Tropentag 2023

International Research on Food Security, Natural Resource Management and Rural Development

Competing pathways for equitable food systems transformation: trade-offs and synergies

Book of abstracts

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Preface

Tropentag is the largest interdisciplinary conference in Europe focusing on development-oriented research in the fields of tropical and subtropical agriculture, food security, natural resource management and rural development. The theme of the Tropentag 2023 is "Competing pathways for equitable food systems transformation: trade-offs and synergies", organised by the Leibniz Centre for Agricultural Landscape Research (ZALF) in cooperation with the Humboldt-Universität zu Berlin, Germany, and will take place from 20-22 September 2023. It is clear that a just and sustainable transformation of our food systems is urgently needed: climate change, conflicts, rising food and fuel prices, and growing social and income inequalities are exacerbating the vulnerabilities of our food systems. But what should the transformation of our food systems look like?

The theme invites diverse contributions that explore different pathways for transforming food systems and the trade-offs and synergies involved, ranging from more technical solutions, such as climate-smart agriculture and biofortified crops, to more systematic solutions for changing the underlying relationships of our food systems, such as agroecology and alternative food networks.

This debate will be explored during the conference by internationally renowned keynote speakers. This year's keynotes will discuss policy and technical innovations to increase the resilience of food systems to shocks; the role of data-driven approaches in identifying opportunities for more sustainable and equitable food system outcomes; the role of micro, small and medium enterprises in supporting inclusive value chain transformation; a framework for analysing and addressing inequalities in food systems; and alternative pathways for food system transformation, including livestock systems and agroecology.

This year we have received over 980 submissions, of which 625 will be presented as either oral or poster presentations – these are now available in this book-of-abstracts. We will have 133 oral presentations grouped into 25 scientific sessions, 47 face-to-face poster sessions and 9 online poster sessions. There will also be 22 pre-conference workshops and 8 post-conference workshops, which broadly engage with this year's conference theme.

This year's featured CGIAR centre is the International Food Policy Research Institute (IFPRI), which provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition in developing countries.

We would like to thank all the participants for their scientific contributions and our colleagues on the Scientific Committee for reviewing the abstracts and chairing the oral and poster sessions. But the conference could not be organised without the help of many people behind the scenes. We would like to thank Eric Tielkes and his team for their invaluable support in organising this ever-growing event. Special thanks to the student reporters for keeping the blog and reports 'alive'. Thanks also to ATSAF for all the guidance, and to the staff and student volunteers from the Humboldt-Universität zu Berlin for helping to organise this conference. Special thanks to our long-standing donors (listed on the back cover) for their unwavering financial and in-kind support, which allows us to keep conference fees at a modest level, especially for early career researchers. Thank you all for attending – you have made it possible once again.

We welcome you to Berlin from so many different parts of the world and wish you an inspiring and enriching conference.

On behalf of the Tropentag 2023 Organising Team:

Stefan Sieber, Dagmar Mithöfer, Caroline Hambloch, Wolfgang Bokelmann, Heike Schobert, Lisa Brandt, Eric Tielkes

Berlin, September 2023

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Plenary speeches

Achieving resilient food systems

Johan Swinnen

International Food Policy Research Institute (IFPRI), United States

For nearly a decade now, global progress against hunger and malnutrition has stagnated and begun to reverse. Countries around the world now grapple not only with rising food and nutrition insecurity but also with the three C's: Climate Change, COVID-19, and Conflict. While food and commodity prices have come down from their peak, they remain historically high. In fact, price shocks and other shocks may be the new normal. In his presentation, Dr. Johan Swinnen will discuss the impacts of climate change, the global pandemic, and the food and fertiliser crisis, as exacerbated by Russia's invasion of Ukraine. Different regions, countries, and segments of the population remain more vulnerable than others to these types of shocks. Dr. Swinnen will draw from IFPRI's latest research and modelling tools, to identify policy and technical innovations that can help policymakers transform food systems so they are resilient against shocks, inclusive of marginalised populations, and environmentally sustainable.

Contact Address: Johan Swinnen, International Food Policy Research Institute (IFPRI), Washington, United States, e-mail: j.swinnen@cgiar.org

The interplay of agriculture, land use, climate change, and food security

Catherine Nakalembe

University of Maryland, Dept. of Geographical Sciences, United States

Food security in sub-Saharan Africa is a critical issue, with approximately 140 million people facing acute food insecurity, according to the 2022 Global Report on Food Crises. To address this challenge effectively, understanding the dynamics of land use, climate change impacts on agricultural productivity, and factors influencing food access and resource distribution is crucial. This talk delves into the complex interplay between agriculture, food security, land use, and climate change in sub-Saharan Africa, exploring sustainable pathways and the role of remote sensing and machine learning technologies in enhancing decision-making. We can identify opportunities for more sustainable and equitable solutions by utilising data-driven approaches, especially concerning regional food security. The talk emphasises the potential for these technologies to drive positive change on a large scale.

Contact Address: Catherine Nakalembe, University of Maryland, Dept. of Geographical Sciences, College Park, United States, e-mail: cnakalem@umd.edu

Food system transformation through the lenses of nutrition and equity

Jody Harris

World Vegetable Center, Food Systems East and Southeast Asia, Thailand

Food systems are currently not delivering food security and good nutrition for all. Classically, it is the most marginalised groups in a given society who are most malnourished and least able to engage with food systems to obtain a healthy diet. So we need to acknowledge this, and understand who is marginalised and why and how, in order to transform food systems to leave no-one behind.

Marginalisation is the key concept that underpins inequity. We know that much food systems and nutrition research concerns itself with aspects of marginalisation, for instance the disempowerment of women, or disparities in income. But other axes of marginalisation, such as age, ethnicity, disability, sexuality, and geographic marginalisation come up far less often in the food systems literature, when looking at who has these different outcomes. The interactions between these different aspects of marginalisation – intersectionality – are studied even less often. And the structural determinants of marginalisation – inequitable access to basic services, resources and political redressal; and power relations and social norms – are also under-explored in our field.

This keynote will present the Nutrition Equity Framework, to provide a logic for how researchers and practitioners can acknowledge, assess and address inequity in food systems; and offer insights from the new UN-CFS High Level Panel of Experts report on addressing inequality and inequity in food systems for food security and nutrition. The talk will argue not for a specific transformation approach, but rather for considering nutrition among key food system outcomes; and equity as key to the process of negotiating transformation and change.

Keywords: Food systems

Contact Address: Jody Harris, World Vegetable Center, Food Systems East and Southeast Asia, P.O. Box 42, 74151 Shanhua, Tainan, Thailand, e-mail: jody.harris@worldveg.org

ID 951

Rethinking agricultural strategies for Africa: Moving beyond the green revolution to embrace agroecology

Million Belay

General Coordinator, Alliance for food sovereignty in Africa and Panel Member IPES Food, Uganda

This presentation advocates for a fundamental shift in African agricultural strategies, urging a departure from the conventional Green Revolution approach and a move towards embracing agroecology. The limitations of the Green Revolution, including environmental degradation, high production costs, and vulnerability to pests and diseases, are discussed, highlighting the need for a more sustainable and inclusive alternative. Agroecology, grounded in ecological principles and local knowledge, offers a context-specific and climate-resilient pathway to transform African agriculture. By prioritising biodiversity, sustainable resource management, and farmer empowerment, agroecology can address food security challenges while promoting environmental sustainability and social equity. The speech presents successful examples and research findings that underscore the positive impacts of agroecology on food security, biodiversity conservation, climate adaptation, and rural livelihoods in diverse African contexts. Embracing agroecology enables Africa to create resilient and equitable agricultural systems that tackle climate change and resource constraints while safeguarding community well-being and ecological integrity.

Contact Address: Million Belay, General Coordinator, Alliance for food sovereignty in Africa and Panel Member IPES Food, P.O. Box 571, Kampala, Uganda, e-mail: million.belay@afsafrica.org

The roles and potentials of micro, small and medium scale enterprises for inclusive value chains in developing regions

Lenis Saweda Liverpool-Tasie

Michigan State University, College of Agriculture & Natural Resources, United States

In the last three decades, agri-food value chains (AVCs) have been growing and transforming rapidly in developing regions. This transformation is driven in part by urbanisation, population & income growth, and market deregulation. These have caused shifts in consumption patterns which have stimulated significant supply response; largely domestic. This transformation has been facilitated by enormous aggregate investment on the part of the many micro, small, and medium enterprises (MSMEs) in the "midstream" and "downstream" of AVCs, comprising the wholesale, logistics, processing, and retail segments of value chains. Despite their critical role in making nutritious and safe foods available to consumers, limited attention in research and national or international policy discussions has been directed toward these value chain segments. In this talk, I will draw from several research projects to reflect on the potential roles of these MSMEs (particularly in the midstream and downstream of food supply chains) in making the transformation of these value chains more inclusive and the associated implications for policy and research.

Contact Address: Lenis Saweda Liverpool-Tasie, Michigan State University, College of Agriculture & Natural Resources, East Lansing, United States, e-mail: lliverp@msu.edu

ID 986

Competing narratives for livestock development and policy

Ian Scoones

PASTRES, Institute of Development Studies, University of Sussex, United Kingdom

This presentation will offer a new narrative for livestock development and policy, focusing on extensive livestock and pastoral systems from across the world. Making use of half the world's land surface, rangelands are an important site for the production of animal-source foods and other products, generating livelihoods for millions. Yet extensive livestock systems are poorly understood, with herders and their livestock frequently cast as the villains of climate change and environmental destruction. The new narrative challenges these assumptions and suggests alternative pathways for development and policy around five intersecting themes: mobility, land and environment, climate, diets and markets. The new narrative highlights the potentials for livestock systems to enhance the environment and biodiversity, while limiting impacts on the climate. The narrative in turn means development pathways that recognise pastoralism and extensive livestock production as productive, modern systems based on mobility, flexibility and adaptability, and embedded in local social relationships and collective networks.

Contact Address: Ian Scoones, PASTRES, Institute of Development Studies, University of Sussex, Brighton, United Kingdom, e-mail: ian.scoones@gmail.com

Crops and cropping systems

Crop production and management

Online posters

Irrigation alone cannot counteract adverse climatic effects on macadamia yields in South Africa

Thomas Bringhenti[1], Issaka Abdulai[1], Munir Hoffmann[2], Elsje Joubert[3], Marco Moriondo[4], Reimund P. Rötter[1], Peter Taylor[5]

[1]*University of Göttingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany*
[2]*AGVOLUTION GmbH, Germany*
[3]*Levubu Centre for Excellence, South Africa*
[4]*National Research Council of Italy, Institute of BioEconomy (CNR-IBE), Italy*
[5]*University of the Free State, Zoology and Entomology Department and Afromontane Research Unit, South Africa*

Macadamia is a high value tree nut crop experiencing a considerable rise in global demand. South Africa is the world largest producer of macadamia nuts, with production areas rapidly expanding in the country. However, yields are highly variable and have been declining in recent years, in conjunction with increasingly severe climate change impacts in the region. Therefore, to sustainably increase the productivity and climate-resilience of macadamia orchards, the effect of environmental factors on the trees' vegetative and reproductive cycles needs to be better understood. To this end, we quantified the extent to which climatic and soil factors drive macadamia yields in Levubu (South Africa) along an altitudinal gradient (600–950 m a.s.l.), for irrigated and rainfed orchards, separately. For this we applied mixed-effects models on historical production data for the years 2010–2021 from 247 orchards. On this background, the role of irrigation in counteracting the impact of abiotic stresses on macadamia phenology and productivity was evaluated.

We found a pronounced interannual variability of macadamia yields (from 1.2 to 4.0 tons dry nut-in-shell ha^{-1}). Higher yields were found at elevations >700 m a.s.l. and in micro-sprinkler irrigated orchards. Orchard characteristics and environmental variables jointly explained 49 % of the yield variability. Cultivar, presence of irrigation, tree age and planting density were found to affect yield, while no significant effect was found for soil variables. High temperatures and low global radiation during the nut development stages, alongside poor rainfall amounts in the dry season, were the climatic factors more severely affecting yields. In particular, low irradiance was the main yield limiting factor in irrigated orchards, while extremely high temperatures and poor rainy seasons were most limiting in the rainfed ones. Increased irrigation amounts, although beneficial, were not fully compensating the impact

Contact Address: Thomas Bringhenti, University of Göttingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Grisebachstr. 6, 37077 Goettingen, Germany, e-mail: thomas.bringhenti@uni-goettingen.de

ID 599

of climatic factors on productivity. Our findings suggest that irrigation alone cannot counteract adverse climatic effects on macadamia yields. To sustainably increase macadamia productivity and resilience to climate change, abiotic stress impacts will have to be reduced through a combination of improved orchard management and breeding for stress tolerance.

Keywords: Abiotic stress impact, altitudinal gradient, climate change, irrigation systems, *Macadamia* spp., yield limiting factors

Change along the way? Balancing systems approach and comparability when adapting long-term experiments

Eva Goldmann, Akanksha Singh, David Bautze, Laura Armengot, Johanna Rüegg, Marc Cotter, Noah Adamtey, Amritbir Riar, Beate Huber

Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

SysCom was initiated to provide evidence for the performance and viability of organic agricultural cropping systems in the tropics. While case studies and long term studies were available for temperate zones, little scientifically backed-up evidence was available to assess the potential of organic agriculture in sustainable development in countries within the tropical climate. Thus in 2007 long term trials in India, Bolivia and Kenya were established, comparing in each country two organic systems with two conventional systems based on locally relevant cropping systems and main crops (cotton, cocoa, maize). Combining the existing practical examples and recommendations from local agricultural institutions organic and conventional treatment were designed, putting high emphasis on the local relevancy and prevalent practices. After the systems established it became clear that organic systems in our long-term experiments (LTEs) were lacking behind in profitability and productivity, not offering a valuable approach for local farmers to sustain their livelihoods. In our analysis we had to realise that often a mere copy of conventional practices, substituting conventional with organic inputs would not suffice to provide solid evidence on the potential of organic agriculture in the tropics.

Using the example of the SysCom program, we want to discuss the challenges and opportunities of adapting LTEs, confronting questions on how to adapt the three LTEs implemented in different countries to still be in nexus to each other, how to balance systems approaches to optimise the different compared treatments while still being comparable to each other and finally how to meet the golden mean of innovative and optimised farming approaches while being realistic and relevant to local contexts. The adaptations realised in the annual cropping system LTEs, such as changing input levels and seed material, introducing more complex intercropping patterns and crop rotations are proving to be valuable additions to our experiments. The positive impacts on productivity and profitability, especially on the organic systems can serve as a examples of sustainable locally adapted production systems, allowing also smallholder farmers to sustain their livelihood also in the future on farming.

Keywords: Annual cropping systems, cotton, India, Kenya, long-term trial

Contact Address: Eva Goldmann, Research Inst. of Organic Agriculture (FiBL), International Cooperation, Ackerstrasse 113 Box 219, 5070 Frick, Switzerland, e-mail: eva.goldmann@fibl.org

Improving the productivity of the sorghum-cowpea intercropping systems through varietal diversity in Sudano-Sahelian zone of Burkina Faso

AMINATA GANEME[1], TRAORÉ SALIFOU[1], LOUIS MARIE RABOIN[2], DUSSERRE JULIE[3], KONDOMBO CLARISSE PULCHÉRIE[4], DOUZET JEAN-MARIE[3], ZABRE YACOUBA[5], MYRIAM ADAM[6]

[1]*Joseph Ki-Zerbo University, Plant Biology and Ecology Laboratory, Burkina Faso*
[2]*Univ. Montpellier, CIRAD, France*
[3]*AIDA, Univ. Montpellier, CIRAD, France*
[4]*National Inst. of Environment and Agronomic Research, Burkina Faso*
[5]*Rural development institue, Burkina Faso*
[6]*CIRAD, AGAP, France*

Cereal-legume intercropping systems are one of the most commonly practised cropping systems in Sub-Saharan Africa. Despite their multiple agroecological, crop yields remain low in the Sudano-sahelian zone of Burkina Faso. Our study aims to improve the productivity of this intercropping system through the use of varietal diversity. Specifically, it aims to (i) characterise the type of sorghum-cowpea intercropping most commonly practised by farmers, (ii) identify the most productive sorghum and cowpea varieties, and (iii) identify the agro-morphological traits of varieties that influence productivity in this system. Surveys of 170 farmers and monitoring of 80 farmers' plots were carried out in the Centre-Nord region of Burkina Faso. Sorghum (13) and cowpea (11) varieties, selected in a participatory manner, were evaluated in intercropping systems during the 2018 and 2019 seasons, at Saria research station. The results showed that intercropping in the same seed hole is the most practised cropping system with 98 % of respondents. It is mainly practised with local varieties (92 % for sorghum and 67 % for cowpea). Yields measured on farmer' fields were highly variable (CV $\Box$ 40 %) and low (average $\Box$ 500 kg.ha^{-1}) for both crops. Intercrops were relatively more productive than the corresponding sole crops for all varieties with land equivalent ratios (LER) ranged between 1.00 and 1.79. Optimal productivity combinations were obtained with the sorghum varieties CSM 63E, Pisnou and PSE08 G1/21–1G1, and the cowpea varieties Kvx396–4-5–2D, Yiisyande, Niizwe and Tiligré. Sorghum cycle duration (r=-0.49), plant height (r=+0.60), and chlorophyll content in sorghum leaves (r=+0.66) were traits that most influenced grain yields of sorghum when intercropped. Cowpea cycle duration (r=-0.25), branching length (r=+0.30), and competitiveness ratio (r=-0.31) were the most influential cowpea traits on sorghum grain yield. The varieties identified could be proposed to farmers for improved productivity.

Keywords: Agro-morphological traits, grain yield, intercropping, land productivity

Contact Address: Aminata Ganeme, Joseph Ki-Zerbo University, Plant Biology and Ecology Laboratory, Secteur 42 ouagadougou, 596 Ouagadougou, Burkina Faso, e-mail: amiganame@yahoo.fr

Water use efficiency and the net ecosystem C balance assessments from rice cultivation in Benin

Coffi Leonce Geoffroy Sossa[1], B. Jesse Naab[1], Augustin Juergen[2],
Souleymane Sanogo[3], O. Luc Sintondji[4], Mathias Hoffmann[2]

[1]*West African Science Service Center on Climate Change and Adapted Land Use, Benin*
[2]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Isotope Biogeochemistry and Gas Fluxes, Germany*
[3]*Université des Sciences, des Techniques et des Technologies de Bamako (USTTB), Lab. of Optics, Spectroscopy and Science of Atmosphere (LOSSA), Mali*
[4]*Université d'Abomey-Calavi, Inst. National de l'Eau, Benin*

The water use efficiency (WUE) and net ecosystem carbon (C) balance (NECB) are key indicators of agroecosystems, used to describe the trade-off between yield on the one hand, and required water and soil C loss/gain on the other hand. Considering the different farming practices, sustaining, or even increasing yields while improving water use and limiting carbon loss is therefore vital for sustainable agriculture. Here, we seek to assess the WUE and the NECB from rice cultivation as affected by different water management and N fertiliser rates in southern Benin. A field experiment was established from November 2022 to March 2023 at Koussin lélé, Cove district, using a split-plot experimental design. The main plots are different water management measures, which include continuous flooding (CF) and two thresholds (at 15 cm and 30 cm below surface) of alternate wetting and drying (AWD) irrigation (AWD15 and AWD25). The subplots are two rates of N fertiliser that include 90 kg ha^{-1} (farmer's practice) and 120 kg ha^{-1} (high amount of fertiliser). WUE and the NECB were assessed based on dynamic, manual closed chamber (A: 0.16 m^2; V: 0.16 m^3) measurements of evapotranspiration (ET), ecosystem respiration (Reco), and net ecosystem exchange (NEE), which were performed biweekly with a novel, low-cost ET, and CO$_2$ flux logger system. Measured CO$_2$ and ET fluxes were calculated using modular R scripts. The results showed that the agronomic WUE (yield (g)/ET (mm)) ranged from 1.63 g mm^{-1} to 2.36 g mm^{-1} and was highest under CF and AWD15 with N90 (statistically similar). All the treatments were small C sinks. The highest negative NECB (atmospheric sign convention) was recorded under CF with N120 (-30.98 g C m^{-2}) whereas the NECB was recorded under AWD15 with N120 (6.28 g C m^{-2}). The increase in negative NECB was in the order CFN90 > AWD15N90 > CFN120> AWD25N90 > AWD25N120> AWD15N120. In addition, the grain yield under CF and AWD15 are statistically similar. Therefore, we recommend adopting the AWD15 irrigation regime with an application rate of N 90 kg ha^{-1} for sustainable irrigated rice production.

Keywords: N fertiliser, NECB, rice, water management, water use efficiency

Contact Address: Coffi Leonce Geoffroy Sossa, West African Science Service Center on Climate Change and Adapted Land Use (WASCAL), Climate Change and Agriculture, Abomey Calavi, Benin, e-mail: sogeof1992@gmail.com

Environment-specific selection of high-quality cotton cultivars from on-station and on-farm trials

Alexander Heer, Tanay Joshi, Monika Messmer, Amritbir Riar

Research Inst. of Organic Agriculture (FiBL), Switzerland

Selecting qualitatively high cotton cultivars is a critical aspect of cotton breeding programs. However, choosing cultivars is not straightforward. Genotype × environment (G×E) interactions have to be considered when choosing varieties for cultivation. This holds especially true in organic farming where natural stress resistance is crucial in the absence of genetic modifications.

For on-station trials, GGE biplots have become a popular tool for selecting cultivars. We applied the method to data from our on-station trials conducted at five sites in India and for 29 cotton cultivars. The sites included different farming conditions and the cultivars were a mix of hybrids and non-hybrids from the *Gossypium hirsutum* and *Gossypium arboreum* species. Using the PPBstats package in R, we identified suitable varieties for each site. Cultivar performance varied greatly between sites. Varieties bred at a site performed particularly well, showing the importance of environment-specific breeding.

On-farm trials are a participatory breeding approach that enables farmers to participate directly in the decision-making. However, estimating G×E effects is difficult due to the trial design. To analyse our on-farm trials conducted on 102 farms in India, testing 32 *G. hirsutum* and *G. arboreum* varieties, we applied a hierarchical Bayesian G×E model. The analysis was done using the PPB-stats package in R. Farm clusters in which the tested cultivars performed similarly were identified. Well-performing varieties for each cluster were found through mean comparisons within each farm. Furthermore, a GGE biplot analysis was performed by pooling farms along agroclimatic zones to identify suitable cultivars on an agroclimatic level. The preliminary results from the GGE biplots have lower precision for the individual farmers that participated in the trials than the hierarchical Bayesian method but can be used for giving recommendations to policymakers and stakeholders for selecting cultivars based on agroclimatic zones. Thus, the combination of the two approaches can be used for decision-making on G×E cultivar selection through on-farm trials while providing participating farmers with tailored recommendations for their own cultivation.

Keywords: Cultivar selection, genotype by environment interaction, on-farm trials, on-station trials, organic cotton, site-specific breeding

Contact Address: Alexander Heer, Research Inst. of Organic Agriculture (FiBL), Frick, Switzerland, e-mail: alexander.heer@fibl.org

Adapting the CROPGRO model to simulate biomass production and soil organic carbon of *Brachiaia* cv. hybrid Cayman and *Panicum maximum* in East Africa

Sylvia Sarah Nyawira[1], Mercy Korir[1], Ken Boote[2], Leonardo Ordonez[3], An Notenbaert[1], Gerrit Hoogenboom[2]

[1]*The Alliance of Bioversity International and CIAT, Tropical Agriculture, Kenya*

[2]*University of Florida, Agricultural and Biological Engineering Dept., United States*

[3]*International Centre for Tropical Agriculture, Climate Action, Colombia*

Biophysical models are key to inform management activities that can restore degraded soils and ultimately improve biomass production and soil organic carbon (SOC) sequestration. Within East Africa several studies have been conducted to evaluate models in annual cropping systems, and to quantify the impacts of different agronomic management options on soil organic carbon and yields. However, no modelling studies exist on perennial forage grasses, which are important for mixed-crop livestock systems within the region. We evaluate the CROPGRO-Perennial Forage model (CROPGRO-PFM) using harvested biomass and SOC data from several sites across Kenya and Tanzania. The model version initially parametrized for *Brachiaria* cv. Marandu and *Panicum maximum* in Brazil is applied to simulate *Brachiaria* cv. hybrid Cayman and *Panicum maximum* in the two countries. We modify model parameters to improve d-statistic and root mean square error (RMSE) for biomass and SOC. Our results show that the CROPRO-PFM model can simulate biomass of *Brachiaria* cv. Cayman under different soils and weather conditions with an acceptable adjustment of parameters including soil water (lower limit, drained upper limit, saturated water content) and stable soil organic carbon. The d-statistic for harvested biomass across the Tanzania sites ranged between 0.78 to 0.97, while the root means square error ranged between 0.6 to 2 t ha^{-1}. Sensitivity simulations with increased manure application rates of 5 t ha^{-1} show an increase in SOC of up 0.833 t ha^{-1} yr^{-1}. These results suggest that the CROPGRO-PFM can be used to simulate growth of *Brachiaria* cv. Cayman adequately under rainfed conditions in the East African highlands.

Keywords: Biomass, *Brachiaria*, Kenya, perennial forage model, soil organic carbon, Tanzania

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Nitrogen fixation and nitrous oxide emissions in tropical silvopastoral systems based on *Urochloa* grasses and *Leucaena* shrub legume

Daniel Mauricio Villegas[1], Julian Rivera[2], Julián Chará[2], Enrique Murgueitio[2], Jacobo Arango[1]

[1]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia*
[2]*Center for Research on Sustainable Agricultural Production Systems - CIPAV, Colombia*

Cattle production in tropical regions is largely dependent on monoculture pastures, which are characterised by low technology adoption and high land occupation. The introduction of legumes in tropical pastures has been proposed as a potential alternative to increase forage and animal productivity while maintaining soil quality without the use of synthetic inputs. However, the impact of increased nitrogen inputs via symbiotic fixation by legumes on soil nitrogen gaseous losses has received limited attention. To evaluate the potential of shrub legumes to improve nitrogen cycling in pastures of Valle del Cauca, Colombia, we conducted a one-year study from 2021 to 2022. Four pasture treatments, including *Urochloa* hybrid cv. Cayman and *U. brizantha* cv. Toledo alone and in association with the shrub legume *Leucaena diversifolia*, were evaluated. We measured plant biomass production, forage nitrogen uptake, nitrogen fixation of *L. diversifolia*, and nitrous oxide emissions from soil after the application of urine patches in the pastures. Pasture treatments associated with *L. diversifolia* produced up to 36 % more forage biomass and showed up to 50 % higher nitrogen concentration in leaf tissue than the Cayman and Toledo grasses growing alone. Furthermore, the proportion of nitrogen derived from the atmosphere in *L. diversifolia* was estimated to be around 50 %. Although absolute nitrous oxide emissions after the application of urine patches were higher in pastures associated with *L. diversifolia*, the increase in forage production per unit area led to up to 18 % lower intensity of emissions than in grass alone pastures. Our findings suggest that integrating *Urochloa* grasses with legumes such as *L. diversifolia* is a promising alternative to sustainably intensify animal production without increasing gaseous N losses.

Keywords: Forage quality, livestock, nitrogen losses, pasture productivity

Do groundnut haulm quality influence farmers decision on variety adoption? An explorative study from an eastern Indian state

Nils Teufel[1], Braja Swain[2], Isabelle Baltenweck[1]

[1]*International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kenya*
[2]*International Livestock Research Institute, PIL, India*

Crop residue contributes major shares (61 %) of total dry matter intake in mixed crop-livestock systems, while dual-purpose crops play an important role-grain provides feed for human and crop residue used as feed for the livestock and will continue as available land is declining due to urbanisation and population growth. Groundnut is one of the important dual-purpose crops, where its haulm provides high-protein to ruminants especially in low-rainfall/dry land agro-economy system. Identifying the improved variety having both high pod yield and better haulm quality and disseminating will have high positive impact on the livestock productivity. Having importance of groundnut for both food and feed, ICRISAT and ILRI embarked on selecting superior varieties of groundnut in India having better pod yield and nutritive quality of their haulms since 2006. As a result, a new improved variety namely ICGV91114 was identified and released nationwide in 2007 including Odisha. This variety (local name 'devi') was successfully adopted by the government system and also widely adopted by farmers in Odisha.

In this context, the study aimed to provide both qualitative and quantitative insights into the adoption of 'devi' variety by the farmers through focus group discussion covering 439 villages from 9 districts. Two stage sampling methods were followed to identify the villages.

Farmers' choice of adopting groundnut variety depends on various factors like grain yield, availability of seed, availability on time, haulm quality, haulm yield and such others. We observed that adoption of particular groundnut variety is depending upon the grain yield followed by seed availability in particular time (especially during planting period) and haulm quality. Though, farmers prefer to grow 'devi' variety as it has high pod yield and better haulm quality, due to non-availability of seed, farmers plant other varieties that are available during the planting period (January-February). While disseminating the devi variety, stakeholders involved in the releasing process did not consider the haulm quality, only focused pod yield. Therefore, to improve the adoption of improved dual-purpose groundnut or any other crop, there needs to disseminate the information on benefits of dual-purpose crops among farmers, improve the seed value chain system and marketing.

Keywords: Adoption, dual-purpose crop, groundnut, haulm quality

Contact Address: Braja Swain, International Livestock Research Institute, PIL, NASC Complex, DPS Satri Marg, , 110012 New Delhi, India, e-mail: brajacds@gmail.com

ID 831

Alternative agricultural approaches for the South: All the same or clear distinctions?

Robert Schäfer, Bernhard Freyer

University of Natural Resources and Life Sciences, Vienna (BOKU), Div. of Organic Farming, Austria

The objective of this study is to assess alternative agricultural approaches that have the potential to cope with the multiple crises smallholder farmers in the South are confronted with.

Agri-food systems have been identified to contribute to soil degradation, loss of biodiversity, and greenhouse gas emissions at least substantially. Meanwhile, the threat particularly to livelihoods in areas of the global south intensifies but the challenges go beyond environmental aspects. The mineral fertiliser crisis – high prices, accessibility, and lack of delivery in time –, while alternative approaches to fill the gap are lacking, is further increasing food insecurity. Equally, the role of socioeconomic and political disturbances becomes more and more apparent and necessitates addressing contemporary and future crises of agri-food systems.

Today, we are confronted with a plethora of approaches that aim at transforming agricultural systems towards a more sustainable relationship between humankind and the environment. Consequently, many of these introduce innovations in the composition of crops, technology, and applied practices but likewise address the social and ethical dimensions of agriculture. The manyfold approaches lead to a lack of clarity for all actors coping with agriculture.

Addressing this complexity, we selected six agricultural approaches for further analysis based on their agroecological potential, their transformative claims, the variety of their methods/practices, and their current distribution: Conservation tillage, evergreen agriculture, holistic management, regenerative agriculture, syntropic agriculture, and organic agriculture are all approaches that have shown promise in improving sustainability in agriculture. As they focus on different ways to tackle environmental and social issues and employ different practices, we argue that there is no one-fits-all solution to every/each future challenge and trade-offs are necessary.

We differentiated these systems according to their ecological, cultural, economical, and market potentials, and assessed their strengths and weaknesses against a set of ecological and socio-economic criteria, to provide a comprehensive overview and subsequently identify merging potential and possible synergies. Doing so, we refer to scientific literature defining and assessing these agricultural approaches.

We finally examined the applicability of those approaches to smallholder farms in (sub-)tropical surroundings and conclude with policy recommendations.

Keywords: Agri-food systems, conservation tillage, evergreen agriculture

Contact Address: Robert Schäfer, University of Natural Resources and Life Sciences, Vienna (BOKU), Div. of Organic Farming, Gregor-Mendel-Straße 33, 1180 Vienna, Austria, e-mail: schaeferro@students.boku.ac.at

Life cycle inventory of soybean production systems in Minas Gerais and Paraná states, in Brazil

Reussite Malembaka[1], Braida Thom[1], Rosangela Cintrão[2], Marie Sigrist[1], Stefan Pfister[3], Johanna Jacobi[4]

[1]*ETH Zurich, Agroecological Transitions Group, Switzerland*
[2]*UFRRJ, Centro de Referência em Soberania e Segurança Alimentar e Nutricional (Ceresan), Brazil*
[3]*ETH Zurich, Ecological System Design Group, Switzerland*
[4]*University of Bern, Centre for Development and Environment, Switzerland*

Soybean (*Glycine max* L.) is among the major grains produced globally as it is an efficient source of proteins and lipids, mainly used as animal feed, food, oil and biofuel. Brazil is the current global leader in production, with soybean grown in all its biomes. Soybean system is facing multiple sustainability crisis as its intensive production is driving environmental crises such as deforestation, biodiversity loss, soil degradation, water scarcity and pollution, and thus climate change. Alternative systems such as organic or the claimed 'sustainable' production are emerging. There is, therefore, a need for a comprehensive understanding of environmental impacts of different soybean productions systems. While many Life Cycle Inventory (LCI) studies of soybean AFVCs have emphasised on intensive production systems, often with carbon footprint as the main impact category, there is still a research need to cover alternative production systems, with more relevant impact categories. The aim of this research is to provide a detailed LCI of soybean production systems in Paraná and Minas Gerais states in the Atlantic Forest biome. Data has been collected through surveys, interviews, and observations, and will be complemented with scientific literature data and the Ecoinvent 3.9 database. The inventory from cradle to farm gate has revealed four soybean production systems: conventional, organic, transgenic, and 'sustainable'. The direct planting, weed control, biofertilisers and bioinputs production on farms were found to be among the factors hindering sustainable and organic soybean intensification. Intercropped soybean with coffee seemed to use smaller machinery but more fuel as huge machines seem to save fuel but at a high ecological cost of soil compaction and biodiversity loss. The inventory analysis is ongoing and will be followed by impact assessment using brightway2. By the end of this and subsequent research objectives, we will have provided evidence on where environmental loads and savings take place in different production systems of soybean, consumed, and wasted. With the broad range of impacts quantified, this work will raise awareness and show environmental trade-offs on the level of soybean footprints in Brazil, for improvement of sustainability research and decisions in soybean food system.

Keywords: Agroecology, Brazil, footprint, soybean production systems, sustainability

Perception of smallholder farmers on efficacy of ecological farming in Chiradzulu district, southern Malawi

Yamikani Makwinja[1], Gift Piyo[2], Veronica Nyirenda[3]

[1]*Technische Universität Dresden, Centre for International Postgraduate Studies of Environmental Management (CIPSEM), Germany*
[2]*China Agricultural University, College of International Development and Global Agriculture, China*
[3]*The Catholic University of Malawi, Geography and Environmental studies, Malawi*

The majority of sub-Saharan countries, including Malawi, heavily rely on cereals such as maize as their staple food. However, climate change and poor farming practices have led to soil degradation, hindering smallholder farmers' ability to increase maize production. This problem is compounded by the escalating costs of inorganic fertilisers, which smallholders are forced to use. This practice also leads to high transaction costs within the value chain system, and increases food prices. Malawi, like many other sub-Saharan countries, is dependent on inorganic fertiliser imports from the global North. Any supply chain disruption, such as the Russian-Ukrainian war, creates a bottleneck that makes fertiliser scarce and expensive, exacerbating food insecurity in the region. To address this issue, there is an urgent need for a radical sustainable option for the farmers. Ecological farming has been proposed as a cost-effective and sustainable alternative to conventional farming that can improve soil health and reduce the dependence on increasingly expensive inorganic fertilisers. However, despite the potential benefits, smallholder farmers in many sub-Saharan African countries, including Malawi, have been slow to adopt ecological farming practices. To understand why this is the case, we examined the perception of smallholder farmers on the efficacy of ecological farming in Traditional Authority Mpama, Chiradzulu district in Malawi. Our study involved five focus group discussions and structured interviews with 120 smallholder households, and we analysed the data using qualitative approaches and the principle of weighted average index. Our findings indicate that at least 60 % of smallholders perceive ecological farming technologies as retrogressive and non-productive. Furthermore, we identified a significant association between socio-economic characteristics of respondents and community perceptions on efficacy of ecological farming. To overcome these barriers, we suggest implementing interventions that improve knowledge levels, attitudes, and behaviours of farmers through capacity building, sensitisation, and mobilisation. We believe that these interventions can effectively promote the adoption of ecological farming among smallholders, leading to increased food security and reduced dependence on expensive and lethal technologies.

Keywords: Capacity building, ecological farming, food security, land optimisation, perceptions, smallholder farmers

Assessment of duplicates in perennial soybean (*Neonotonia wightii*) collection

Alemayehu Teresssa Negawo[1], Alemayehu Demeke Bedane[1], Michael Gashaw[1], Meki Shehabu Muktar[1], Alice Muchugi[2], Alieu Sartie[3], Chris S. Jones[2]

[1]*International Livestock Research Institute (ILRI), Ethiopia*
[2]*International Livestock Research Institute (ILRI), Kenya*
[3]*Seed Systems Specialist, Pacific Community (SPC), Fiji*

Perennial soybean (*Neonotonia wightii* Wight & Arn.) is a herbaceous perennial forage legume that is mainly used as pasture or hay for animals. It is a nitrogen fixing legume that can be grown as a cover or fallow crop and contributes to improved soil fertility and productivity of crops. It is a drought tolerant climate adaptive species with an annual productivity of up to 10 tons DM/ha. The ILRI Genebank holds over 400 accessions with little information on the collection. Generating information and understanding the collection through genotyping and phenotypic characterisation is necessary to promote greater use and to rationalize and efficiently curate the collection. Preliminary passport data assessment showed some potential duplicates in the collection. In line with this finding, we used a molecular approach to study the identified potential duplicates. Genomic DNA was extracted from young leaves collected from healthy growing seedlings in the greenhouse and sent for genotyping at SEQART, ILRI Nairobi, Kenya. The generated genotyping data were used to assess the genetic distance/similarity among the accessions. Visualisation of the hierarchical clustering, principal component analysis, genetic relationship matrix and genetic distance were used to assess the genetic relationship of the accessions. The result showed the accessions are differentiated from each other with varying level of genetic distance (0.123–0.370 Roger distance and 0.4687–0.9136 Hamming distance). Thus, the result from this study demonstrates that genotyping data can be used to complement the passport and phenotypic data to assess potential duplicates and for efficient curation of germplasm in the genebank.

Keywords: Duplicates, genebank, genetic distance, germplasm, perennial soybean

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Assessment of slow-growth treatments to develop an efficient *in vitro* medium-term conservation method for garlic (*Allium sativum* L.)

Stacy Denise Hammond Hammond[1], Hynek Roubik[2], Jiri Zamecnik[1], Bilavcik Alois[1], Olena Bobrova[1], Milos Faltus[1]

[1]*Crop Research Institute, Division of Plant Physiology and Cryobiology, Czech Republic*
[2]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic*

The study aimed at assessing various osmotic agents and plant growth regulators at varying concentrations to determine their effect on growth reduction to develop an efficient slow-growth storage protocol for the medium-term conservation of garlic (*Allium sativum* L.). Osmotic agents, sorbitol (20–60 g l^{-1}), mannitol (20–60 g l^{-1}), and sucrose (30–150 g l^{-1}) and plant growth inhibitors chlorcholinchlorid (CCC) 200–600 mg l^{-1} and abscisic acid (ABA) at 1–5 mg l^{-1} were tested as media supplements in combination with 18 ± 1°C cultivation temperature to determine their effect on growth reduction. Full-strength and ½ concentrated MS were used as basal culture media and control. Preliminary findings after a 5-month treatment time duration show that MS medium is more effective in reducing plant growth in combination with the tested media supplements, while ½ MS is not effective in further reducing plant growth, demonstrating a stimulating effect on growth even in combination with the tested media treatments. Overall, MS media +ABA treatments (1, 3 and 5 mg l^{-1}) proved to be the most efficient in inducing slow-growth, with plantlets reaching an average height of just 2.1 cm, 1.4 cm and 1.0 cm, respectively, almost 3 times lower growth compared to the control MS medium (4.7 cm) after the 5-month storage. However, the mannitol treatments proved ineffective and induced hyperhydration (HH) as a form of morphological abnormality. The other treatments also induced slow-growth but were less effective than the ABA treatments. Further research is being conducted to push the boundaries and assess the effect of the tested treatments in reducing the growth of garlic in time. This research will contribute to the development of an efficient medium-term *in vitro* conservation protocol for garlic, the second most important *Allium* species.

Keywords: Osmotic agents, plant growth regulators

Contact Address: Stacy Denise Hammond Hammond, Crop Research Institute, Division of Plant Physiology and Cryobiology, Drnovská 507/73, 16106 Praha 6 - ruzyně, Czech Republic, e-mail: hammond@vurv.cz

Genotypic variation and associated loci for lateral root density and length in rice (*Oryza sativa* L.)

Lam Thi Dinh[1], Nicole Ranaivo[2], Daniel Gonzalez[3], Matthias Wissuwa[4]

[1]*Hirosaki University, Dept. of Applied Biology and Food Sciences, Japan*

[2]*FOFIFA, Rice Research Department, Madagascar*

[3]*Japan International Research Center for Agricultural Sciences (JIRCAS), Japan*

[4]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - PhenoRob Cluster, Germany*

Many abiotic stresses associated with climate change will be most acutely perceived by the plant at the root-soil interface where fluctuations in soil moisture affect water and nutrient uptake. As rainfall patterns change water supply is becoming less predictable and that has caused shifts in rice production systems away from transplanting into flooded fields towards direct sowing into drier soil. The rice root system consists of two lateral root types, indeterminate larger L-types capable of further branching, and determinate, short, unbranched S-types. L-types correspond to the typical lateral roots of cereals whereas S-types are unique to rice. Both types contribute to nutrient and water uptake and our objectives were to assess whether genotypic variation for density and length of these laterals could be exploited in rice improvement to enhance adaptations to nutrient and water-limited environments. A QTL mapping population developed from parents contrasting for lateral root traits was grown in a non-flooded low-P field, roots were sampled, scanned and density and length of lateral roots measured. One QTL each was detected for L-type density (LDC), S-type density on crown root (SDC), S-type density on L-type (SDL), S-type length on L-type (SLL), and crown root number (RNO). The major-effect QTL for LDC on chromosome 5 accounted for 46 % of the phenotypic variation and additional field experiments confirmed that lines with the donor parent allele at qLDC5 had 50 % higher LDC. Simulating effects of allelic differences of main QTL in a P uptake model indicated that qLDC5 was most effective in improving P uptake followed by qRNO9 for RNO and qSDL9 for S-type lateral density on L-type laterals. Pyramiding qLDC5 with qRNO9 and qSDL9 is possible given that trade-offs between traits were not detected. Phenotypic selection for the RNO trait during variety development would be feasible, however, the costs of doing so reliably for lateral root density traits is prohibitive and markers identified here therefore provide the first opportunity to incorporate such traits into a breeding program. Breeding lines combining above QTL are currently being tested without supplementary irrigation in farmers' fields in Madagascar.

Keywords: Crown root, L-type lateral roots, P uptake simulation

Contact Address: Matthias Wissuwa, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - PhenoRob Cluster, Karlrobert-Kreiten-Strasse 13, 53115 Bonn, Germany, e-mail: mc.wissuwa@gmail.com

Survey and collection of solanaceous indigenous plants in central Vietnam

Hoang Pham Le[1,2], Tran Thu Thi Ha[2], Michael Henry Böhme[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*
[2]*Hue University of Agriculture and Forestry, Dept. of Agronomy, Vietnam*

In Vietnam is a visible erosion of genetic resources and a decline in biodiversity, especially solanaceous plants are seriously threatened in Vietnam. Therefore, one aim was to conduct an inventory of the distribution of solanaceous species in farms and local households in central Vietnam in order to understand the level of cultivation. In this study were conducted investigations and surveys in central Vietnam, searching for regions and communities with high cultivation of non-indigenous and indigenous solanaceous plants. Furthermore, an aim was to collect wild solanaceous species in the nature having a value as food or as medicinal plants. In general the aim of the research was focused on the collection of various accessions of solanaceous species in different regions and creation of germplasm database based on morphological characterisation in order to restrict the loss of solanaceous genetic diversity. One of the studies focused on very economically important species, cultivars and landraces for example the genus - eggplants. Indigenous solanaceous genetic resources often lack information on agricultural characteristics, genotypes and phenotypes because they have not been evaluated in detail. The existing database for genetic resources of indigenous Solanaceae plants in Vietnam is underdeveloped because collection, classification and evaluation are not done systematically. This study tried to contribute knowledge in this regard. There are many taxonomic problems with the important indigenous species of the family Solanaceae in Vietnam, particularly as the Solanum genus is highly variable and contain a large number of hybrids. Therefore, identification based on morphological characters is quite difficult. Overall, under-utilised indigenous solanaceous species should be collected, evaluated and conserved. In addition, developing of strategies for germplasm conservation for indigenous genetic resources is necessary.

Keywords: Eggplant cultivars and landraces, genetic resources of solanaceous plants, germplasm conservation, wild solanaceous species

Contact Address: Michael Henry Böhme, Humboldt-Universität zu Berlin, Horticultural Plant Systems, Grünfließer Gang 7, 12587 Berlin, Germany, e-mail: michael.boehme@hu-berlin.de

Participatory bread wheat variety evaluation through seed producer cooperatives in Amhara region, Ethiopia

Dawit Tsegaye Sisay[1], Getnet Share[2], Rebeka Gebretsadik[1], Tadesse Dessalegn[1], Belayineh Getinet[3], Anetneh Demisse[1], Andrea Ruediger[4], Dessalegn Molla[5], Sebsebe Zewde[1], Eshete Abebe[2]

[1]*GIZ / Ethiopia, Ethiopia*

[2]*Adet Agricultural Research Center, Crop Research, Ethiopia*

[3]*West Gojjam Zone Agriculture Office, Crop Production, Ethiopia*

[4]*GIZ / Benin, Benin*

[5]*The Alliance of Bioversity International and CIAT, Ethiopia*

Adoption rate of improved crop varieties in Ethiopia is very low. The absence of engaging farmers and their community agents such as cooperatives in the process of variety testing is one of the main factors for lower rates of variety adoption, which resulted in the lower crop productivity and contributes to weak food systems. Participatory bread wheat variety evaluation (PVE) was conducted by breeders, seed producer cooperative (SPC) and development practitioners with the objectives to identify farmers' selection criteria, to assess farmers' preferred varieties and to increase the SPC's variety portfolios. Role, responsibility and contribution of each actor were defined with prior to the experiment. Researchers were responsible for trial management (design, layout, data collection, analysis, reporting and seed provision), SPC was accountable for land allocation, practice all agronomic practices as per the research recommendations and cover local costs. Local practitioners were responsible in capacity building, field days organisation and follow-up. Eleven released varieties (Wane, Abora, Lemu, Tay, Danda'a, Kakaba, Alidoro, Denbel, Ogolcho, Liben, Buluk) were evaluated during 2020 in Amhara region, Ethiopia. Pair-Wise Ranking Matrix was used to identify farmers' selection criteria and Direct Matrix Ranking to prioritise those selected criteria. Randomised complete block design with two replications was used to evaluate the performance of the varieties both with and without lime applications. Seed yield was identified the first preferred trait by farmers followed by early maturity, disease tolerance, tillering capacity, spike length and biomass yield. Combined mean values showed that higher yield was recorded with the lime application than without. Lemu (6.4 t ha^{-1}), Alidor (6.3 t ha^{-1}), Denbel (6.3 t ha^{-1}), Aboro (6.1 t ha^{-1}) and Liben (6.1 t ha^{-1}) were found the highest yielding bread what varieties with lime application. The t-test results confirmed the significant variations between with lime application and without lime for the number of tillers per plant (0.005), spike length per plant (0.001), plant height (0.000), 1000 seed weight (0.003), and hectoliter weight (0.018), but non-significant variation for grain yield (0.121). The selected varieties should be included in the production plan of the cooperatives for large scale production to increase the variety portfolios and to address the demand of the farming community.

Keywords: Cooperatives, Ethiopia, food systems, participatory variety evaluation

Contact Address: Dawit Tsegaye Sisay, GIZ / Ethiopia, Kolfe Keranio Kefle Ketema, 1000 Addis Ababa, Ethiopia, e-mail: dawit.tsegaye@giz.de

The lateral root architecture of the aus-panel

Helena Bochmann[1,3], Amelia Henry[2], Uwe Rascher[3,1], Josefine Kant[1], Johannes Postma[1]

[1]*Forschungszentrum Jülich, IBG-2, Germany*
[2]*International Rice Research Institute, Stress Physiology and Research, Philippines*
[3]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany*

Drought reduces the grain yield of rice with different intensities in various developmental stages, indicating a need to find well-performing root phenotypes for specific drought scenarios. The aus-panel is known for being stress-tolerant and has a different genetic background from the indica and japonica panel. This makes it a new genetic source for breeding programs under climate change aspects.

To understand and screen the lateral root formation and the variation within the aus-lines, field experiments were conducted during the dry season of 2022 at the International Rice Research Institute (IRRI). In two locations, 206 lines mainly from the aus-panel were sown. Besides measurements like yield and tiller number, crown root samples from the topsoil area were scanned and analyzed. Surface area and length of the main root and lateral root types, number of S-type lateral roots, and the average distance between two S-type lateral roots were measured from this dataset, to serve as an overview of the phenotypic variation within the aus-panel. We found that the lateral root surface area did not increase with the nodal root diameter, but the correlation between these traits was weak ($R^2 < 0.5$). In conclusion, root phenotype variation within the aus-panel can be determined by measuring multiple root traits with a focus on lateral roots and testing their correlation and variation. These root phenotypes will be tested in future experimental and modeling work, to test for beneficial root trait combinations and investigate the role of lateral roots under drought stress and rewatering conditions to contribute to stable food crop security.

Keywords: Aus-panel, drought, lateral roots, rice

Contact Address: Helena Bochmann, Forschungszentrum Jülich, IBG-2, Jülich, Germany, e-mail: h.bochmann@fz-juelich.de

Performance of integrated climate smart push-pull system with pigeon pea as an intensification pathway

Sylvia Buleti[1], Samuel Were[1], Moses Gichua[1], Mary Kamaa Musyoki[2], Shem Kuyah[1]

[1]*Jomo Kenyatta University of Agriculture and Technology (JKUAT), Botany, Kenya*
[2]*University of Hohenheim, DAAD Agriculture-Alumni Network, Germany*

African farming systems are increasingly being intensified to address need for food and challenge on diminishing arable land. Push-pull technology is promoted in western Kenya to sustainably intensify farms and for the management of stem borer, fall armyworm and *Striga* weed. Integration of push-pull systems with other sustainable intensification practices has potential to advance its acceptability and adaptability among smallholders. Push-pull is currently limited in diversity of utility mainly because the companion crops, *Desmodium* (push crop) and *Brachiaria* (pull crop) are not edible. Participatory research carried out among smallholder farmers in western Kenya revealed intercropping, agroforestry and crop-livestock integration as priorities for further intensification of push-pull farming systems. The aim of the study was to determine the effectiveness of push-pull system integrated with pigeon pea (*Cajanas cajan*) on productivity and soil fertility. Field experiments consisting of four treatments (climate smart push-pull (maize + *Desmodium* + *Brachiaria*), push-pull + pigeon pea, maize + pigeon pea, and maize monocrop) were established on fifteen farms in three counties of western Kenya. A section of the plot was demarcated and used for data collection on growth, grain and stover yield. Preliminary results show that growth and yield vary across counties, seasons and treatments. Overall productivity of the intensified system was best in Siaya, followed by Kisumu and Vihiga counties respectively. Push-pull + pigeon pea and maize + pigeon pea were superior in performance based on maize growth and stover yield for season one. Maize + pigeon pea and push-pull performed better in grain yield than push-pull+ pigeon pea and maize monocrop for both seasons. Reduction in yield per unit area resulting from intensification of push-pull with pigeon pea is leveraged by alternative products such as fodder, firewood and diversified diets. Intensification with pigeon pea resulted in better stover and grain yield in the long rain season further it provided additional products such as alternative diets in the dry season of 2022, firewood from twigs and stems, fodder from leaves and pods, soil organic matter from litter and overall system resilience. Diversification of push-pull can guarantee its successful upscaling in East Africa for synergy in sustainable food production and environmental conservation.

Keywords: Biomass, *Brachiaria*, intercropping, pigeon pea, push-pull system, sustainable intensification

Contact Address: Sylvia Buleti, Jomo Kenyatta University of Agriculture and Technology (JKUAT), Botany, 62000, Nairobi, Kenya, e-mail: sylviaimbuhila@gmail.com

Effects of *Tithonia diversifolia* on the growth, secondary metabolites and anticandida activity of *Cymbopogon citratus*

Joseph Blaise Dongmo Lekagne[1], Ruth Ngum Che[2],
Edouard Nantia Akono[2]

[1]University of Yaoundé 1, Cameroon
[2]University of Bamenda, Dept. of Biochemistry, Cameroon

Tithonia diversifolia is a plant advantice with good content in basic minerals including nitrogen, phosphorus and potassium, and has been experienced as an organic fertiliser in some studies. *Cymbopogon citratus* is an aromatic and medicinal plant, well known for its medicinal values such as antifungal and antimalarial properties. This study aimed at evaluating the effect of *T. diversifolia* powder and compost on the growth parameters, total phenolic and flavonoid contents and anticandida activity of *C. citratus*. The plants were cultivated for 8 months in an experimental farm designed as a split plot into 4 blocks. Each block was treated either with *T. diversifolia* compost ($150\,g\,plant^{-1}$), powder ($40\,g\,plant^{-1}$) or the synthetic fertiliser (NPK 20–10-10; $10\,g\,plant^{-1}$) respectively, followed by sprays with same fertiliser treatment on each block every two weeks after transplantation. The control block received no amendment and was sprayed with water. Plant growth parameters (fresh and dry leaves weight, tillers and plant height) were evaluated at four and eight months after transplantation. The harvested fresh leaves were hydro-distilled for essential oil and the hot aqueous extract. Both extracts were used for the evaluation of the anti-candida activity while the latter was submitted to total flavonoids and phenolic analyses. At 4 and 8 months after transplantation, the synthetic fertiliser and *T. diversifolia* compost significantly increased plant growth parameters as compared to other treatments. The plants treated with *T. diversifolia* compost showed higher total phenolic ($61.13 \pm 5.19\ \mu g\ GAE\,mg^{-1}$), flavonoid ($41.17 \pm 10.195\ \mu g\ GAE\,mg^{-1}$), and essential oil content as compared to the plants from other fertilisers. The essential oil from *C. citratus* treated with *T. diversifolia* compost showed the best inhibitory activity on *C. albicans* NR-29451. In conclusion, this study showed that *T. diversifolia* compost was a promising organic fertiliser in optimising the growth, secondary metabolites and anticandida activity of *C. citratus*.

Keywords: Anticandida bioactivity, *Cymbopogon citratus*, plant growth parameters, secondary metabolites, *Tithonia diversifolia*

Biochar and bioslurry production using water hyacinth from Lake Tana / Ethiopia – methodological issues and impact on crop yields

Dessie Tibete[1], Bilhate Chala[2], Tewodroes Mulu[1], Teferi Alem[3], Mohammed Gedefaw[3], Tayachew Nega[4], Marelign Adugna[3], Yezbie Kassa[1], Beatriz Waldmann[5], Tadesse Adgo[6], Christoph Pfeifer[7], Bernhard Freyer[8]

[1]*University of Gondar, College of Natural and Computational Sciences, Ethiopia*

[2]*University of Hohenheim, Inst. for Agricultural Engineering and Bioenergy, Germany*

[3]*University of Gondar, College of Agriculture and Environmental Sciences, Ethiopia*

[4]*University of Gondar, Inst. of Technology, Ethiopia*

[5]*The Nature and Biodiversity Conservation Union (NABU e.V.), Germany*

[6]*The Nature and Biodiversity Conservation Union Ethiopia (NABU e.V.), Ethiopia*

[7]*University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. of Chemical and Energy Engineering, Austria*

[8]*University of Natural Resources and Life Sciences, Vienna (BOKU), Div. of Organic Farming, Austria*

Water hyacinth (*Eichhornia crassipes*) (WH) is an invasive species in Lake Tana, Ethiopia, which infestation increases over the last decade and became a serious issue for fishery and biodiversity of flora and fauna. Furthermore, the WH mats are hosting mosquitos as well as bilharziasis.

Several strategies are discussed to reduce WH infestation: (a) reduction of nutrient flow int the Lake via household and agricultural nutrient input that are the drivers of WH growth; and end of pipe solutions including (b) chemical reduction of the plant population, and (c) technical reduction via harvest strategies combined with the transformation of WH biomass towards products for agricultural purposes. This project focus is on strategy (c). The overall aim of this research is to analyse the whole chain of harvesting, drying, storing, transporting, and preparing the biomass for transforming towards biochar and bioslurry and related residues for composting and biogas production, up to the impact of these fertilisers on crops, using tef (*Eragrostis tef*) as a reference crop.

Findings inform about nutrient content of the diverse parts of WH, the processing characteristics, preparation of the material and logistics and methodological aspects. Furthermore, we inform about the impact on crop yield via different amounts of applications of biochar and bioslurry applications, their combination, additional mineral fertilisers, compared with a non-fertiliser control and farmer's practice.

Contact Address: Bernhard Freyer, University of Natural Resources and Life Sciences, Vienna (BOKU), Div. of Organic Farming, Gregor Mendel Straße 33, 1180 Wien, Austria, e-mail: Bernhard.Freyer@boku.ac.at

A first rough calculation clarifies the relation between WH productivity in the Lake in comparison to the need of nutrients for agricultural production in smallholder communities along the Lake shore, technical challenges logistics, labour, economy and acceptance by the local farmers.

Against the backdrop of the mineral fertiliser crisis - shortages, unavailability, delivery not in time, quality deficiencies, and high prices - alternative organic nutrient fertilisers are of great importance.

Keywords: Biochar, bioslurry, crop yield, fertiliser, Lake Tana, smallholder farmers, water hyacinth

Invasive alien plants and the future of agriculture: Reviewing control approaches in western Serengeti, Tanzania

Peter Mkilindi[1], Katharina Stein[2]

[1]*University of Seoul, International School of Urban Sciences, Republic of Korea*
[2]*University of Potsdam, Biodiversity Research and Systematic Botany, Germany*

Despite its remarkable contribution to ecosystem sustainability and economic development, Serengeti and its surrounding communities are highly affected by invasive alien plants (IAPs). Although some IAPs may have beneficial applications for some communities, such as providing building materials or decoration, they are nonetheless known to be damaging. These plants have extended enormously into farmlands interfering with agricultural production in western Serengeti, the main economic activity in the region and considered the backbone of the country's economy. This study assesses the impacts of IAPs on agriculture and potential control methods in the Bunda and Serengeti Districts of western Serengeti, Tanzania. Data was collected through questionnaires, key informant interviews, and focus group discussions with randomly selected respondents. The study found that while the control of IAPs has been successful in protected areas, it remains a challenge in adjacent community lands. The results indicate that IAPs cause significant threats to local agriculture, soil quality, and biodiversity. Failure to manage IAPs will result in decreased agricultural production, hampering food security and livelihoods in the affected communities. The study recommends early detection and rapid response to new invasions and highlights the need for improved management approaches to address the problem. However, managing IAPs is an expensive initiative that requires significant investment. The study's findings are valuable to farmers, protected area authorities, policymakers, and other stakeholders interested in managing IAPs.

Keywords: Agriculture, biodiversity, control methods, ecosystem, invasive alien plants

Contact Address: Peter Mkilindi, University of Seoul, International School of Urban Sciences, 163 Seoulsiripdaero Dongdaemun-Gu Seoul 02504., Seoul, Republic of Korea, e-mail: peteernest04@gmail.com

Contrasting accessions of tropical forage *Urochloa*: Pioneering tool for the prediction of carbon-soil sequestration

Jana Krtková[1], Mildred Julieth Mayorga[2], Juan Andrés Cardoso[2]

[1]*Charles University, Dept. of Experimental Plant Biology, Czech Republic*
[2]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*

Soil carbon deposition through biomass production as well as plant-soil interface exchange in tropical forage systems may represent huge contribution to ameliorate the increase of carbon dioxide concentration in the atmosphere and thus the climate change. Cattle farming in the tropics is predominantly dependent on pastures with tropical forages. Different accessions of tropical forages, such as *Urochloa humidicola* and its hybrids, display a variety of rooting strategies, root biomass production and suberin deposition, which is hypothesised to contribute to soil carbon deposition. Root morphological traits, such as secondary metabolite deposition in hypodermis and/or endodermis, may represent a versatile phenotyping tool to assess soil-carbon sequestration capacity of tropical forages. We used *Urochloa humidicola*, accession nr. 679, and *U. humidicola* hybrid Bh08 – nr. 1149 to assess root morphology. Root cross sections made from defined relative length revealed less secondary metabolite deposition in hypodermal layers and epidermis, which is coherent with decreased rooting depth, frequent branching, less soil compaction resistance, and thus may coincide with less soil-carbon deposition in 1149 hybrid compared to 679. Further, 1149 roots displayed lower parenchyma cell files number, lower main root thickness, poor aerenchyma development, increased lateral root thickness relative to the main root thickness when compared to 679. In conclusion, we have found two contrasting root morphology phenotypes that perform different rooting strategies. These contrasting genotypes are currently planted under field conditions in Colombia to test their impact upon soil carbon sequestration. Further, an extensive phenotyping will be performed with other numerous accessions, first from hydroponics and later on from natural soil conditions.

Keywords: Carbon sequestration, forage, phenotyping, root morphology

Contact Address: Juan Andrés Cardoso, The Alliance of Bioversity International and CIAT, Trop. Forages Program, Km 17 Recta Cali Palmira, Palmira, Colombia, e-mail: j.a.cardoso@cgiar.org

Relay intercropping of durum wheat and lentil enhances mycorrhizal functionality, weed control and crop productivity

Gilbert Koskey[1], Federico Leoni[1], Stefano Carlesi[1], Luciano Avio[2], Paolo Barberi[1]

[1]*Sant'Anna School of Advanced Studies, Group of Agroecology, Center of Plant Sciences, Italy*

[2]*University of Pisa, Agriculture, Food and Environment, Italy*

Complementary and inter-specific plant-plant associations, like the case of cereal-legume intercrops, drive the recruitment of rhizosphere microbial communities such as the arbuscular mycorrhizal fungi (AMF) important in the provision of ecosystem services that stabilise crop yields and restore soil health. Attempts to assess the impact of intercropping on the functional presence of native AMF communities and their agronomic potential in rain-fed fields remain inconclusive, more so in intercropping systems involving winter-spring crops such as durum wheat and lentils. We carried out a 3-year (2019, 2020, and 2021) field experiment in Central Italy to assess the agronomic performance and mycorrhizal selection of relay intercropped winter durum wheat (*Triticum durum* Desf. cv. Minosse) and spring lentil (*Lens culinaris* Medik. cv. Elsa) under a low-input management system, comparing different crop stand types (monocrop vs intercrop) and intercrop densities (350 plants m^2–100 % wheat dose vs 116 plants m^2–33 % wheat dose). Relay intercropping enhanced lentil grain yield, durum wheat grain protein concentration and P uptake but marginally reduced durum wheat grain yield and lentil grain protein concentration. Both intercropping strategies were effective in controlling weeds and proved beneficial in stabilising the overall yield productivity (LER 164–648 %) compared to sole cropping. Intercropping enhanced soil mycorrhizal activity but differentially influenced mycorrhizal root colonisation compared to sole cropping. Root mycorrhizal analyses via Illumina Miseq sequencing generated a total of 234 amplicon sequence variants belonging to Glomeromycota, which were assigned to 31 virtual taxa using the MaarjAM reference database. Glomeraceae and Claroideoglomeraceae were the most abundant AMF taxa but had contrasting abundances in 2020 and 2021. The overall changes in AMF diversity and community structure were affected by the interaction between crop species and year, and not by intercropping. Claroideoglomus and Septoglomus showed a strong association with lentil roots while Rhizophagus and Paraglomus were associated with durum wheat roots in 2020, affirming a strong host genotype-AMF preference. PCA analysis showed that grain protein concentration was associated with mycorrhizal parameters such as community richness and AMF root colonisation. This study reveals the importance of relay intercropping winter-spring crops in stabilising crop productivity and maintaining soil functionality.

Keywords: AMF community structure, relay intercropping, weed control

Contact Address: Gilbert Koskey, Sant'Anna School of Advanced Studies, Group of Agroecology, Center of Plant Sciences, Piazza martiri della libertà 33, 56127 Pisa, Italy, e-mail: gilbert.koskey@santannapisa.it

The influence of endophytic actinomycetes inoculation in rhizosphere soil on growth and yield quality of tomato

Jeeranan Khomampai[1], Nuttapon Khongdee[2], Thewin Kaeomuangmoon[1], Nakarin Jeeatid[1], Phanumat Ainta[1], Yupa Chromkaew[1]

[1]*Chiang Mai University, Dept. of Plant and Soil Science, Thailand*
[2]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*

The study aims to determine the influence of endophytic actinomycetes inoculation in rhizosphere soil on growth and yield quality of tomato. The experiment was conducted in a net greenhouse at the Agricultural Resource System Research Center, Faculty of Agriculture, Chiang Mai University, Thailand. The randomised completely block design (RCBD) was arranged for 4 treatments with 3 replications, which were (T1) Control (Growing material), (T2) Growing material inoculated with TGsR-03–04 (*Streptomyces violaceorectus*), (T3) Growing material inoculated with TGsL-02–05 (*Nocardiopsis alba*), and (T4) Growing material inoculated with TGsR-03–04 (*Streptomyces violaceorectus*) and TGsL-02–05 (*Nocardiopsis alba*) in tomato. Prior to the experiment, growing material properties analysis and microbial isolation were performed. Isolated actinomycetes of each treatment were inoculated into the root zone of tomato seedlings. Colonisation of actinomycetes into the root of tomato was analysed by Scanning Electron Microscopy (SEM). The height of tomato was measured at 14, 28, 56, and 112 days after transplanting (DAT) and final yield and yield quality of tomato was assessed at the maturity phase. The SEM result illustrated that the root of tomato seedling of all treatments were colonized by endophytic actinomycetes. It contributed to plant height at 14 DAT increased significantly as found in T2 (19.40 cm) compared to the control. Besides, all inoculated treatments enhanced yield and yield quality of tomato. The highest fruit width (42.05 mm), fruit length (53.73 mm), and fruit weight (48.98 g) were obtained by inoculation with the TGsR-03–04 (*Streptomyces violaceorectus*) (T2). There was no statistically difference in the number of fruits per plant and yield per plant when various inoculations of endophytic actinomycete were applied. Therefore, endophytic actinomycete especially TGsR-03–04 could be considerably used to improve the growth, yield and yield quality of tomato.

Keywords: *Lycopersicon esculentum*, *Nocardiopsis alba*, root colonisation, *Streptomyces violaceorectus*

Azolla compost as an alternative source of nitrogen for organic vegetable cultivation

Duy Hoang Vu, Thi Hien Nguyen

Vietnam National University of Agriculture (VNUA), Dept. of Cultivation Sciences, Vietnam

The spread of organic farming in Asia has led to the need to find alternative sources of high quality organic fertiliser. *Azolla* is a genus of floating water ferns that is high in nitrogen and organic matter due to its rapid growth and symbiotic relationship with nitrogen-fixing bacteria (*Anabeana azollae*). It is grown as a green manure in rice fields in many Asian countries. However, little research has been done on the use of *Azolla* as an organic fertiliser for vegetable production. The objective of this study was to evaluate the effects of different levels of *Azolla* compost fertiliser on the growth and yield of Malabar spinach (*Basella alba*) - a popular vegetable crop in the tropics and subtropics - to improve the process of using *Azolla* as an organic fertiliser in vegetable production. The experiment included 6 treatments: Without application-as control (T1); 1 t ha^{-1} soybean meal (T2); 16 t ha^{-1} cow manure (T3); 12 t ha^{-1} *Azolla* fertiliser (T4); 16 t ha^{-1} *Azolla* fertiliser (T5); and 20 t ha^{-1} *Azolla* fertiliser (T6). Our results showed that *Azolla* fertiliser application significantly increased shoot length, number of leaves, leaf size, dry matter, leaf area index (LAI) and SPAD of Malabar spinach compared to control or cow manure. Application of *Azolla* fertiliser at rates of 12, 16, and 20 t^{-1} ha significantly increased the yield of Malabar spinach by 150, 192, and 205 %, respectively, compared to the control and by 37, 60, and 67 %, respectively, compared to the cow manure treatment. Our results suggest that *Azolla* fertiliser can be used as an alternative organic nitrogen source in organic vegetable production. However, genotype selection and rapid multiplication of *Azolla* are necessary to develop it as a nitrogen source that meets the requirements of fast-growing organic agriculture.

Keywords: *Azolla* fertiliser, *Basella alba*, manure, organic vegetable

Contact Address: Duy Hoang Vu, Vietnam National University of Agriculture (VNUA), Dept. of Cultivation Sciences, Ngo Xuan Quang - Gialam, 131000 Hanoi, Vietnam, e-mail: vdhoang87@gmail.com

Title characterisation of the Mayan Milpa system: Maintenance of crop diversity

Kirstine Friis Lange[1], Ida Brix Lassen[1], Ida Theilade[1], Marten Sørensen[2]

[1]*University of Copenhagen, Dept. of Food and Resource Economics, Denmark*
[2]*University of Copenhagen, Dept. of Plant and Environmental Sciences, Denmark*

The Milpa system is a traditional Mayan intercropping system used by small scale farmers in Mesoamerica, which plays a vital role in ensuring food sovereignty and maintaining crop diversity. Despite its importance, small scale farmers are among the poorest in the world and are subject to economic, political, and cultural forces that shape their livelihood strategies and threaten Mayan culture. This study aims to characterise the present Milpa system in El Tablón, Sololá, Guatemala, and examine the farmers' criteria for selecting and conserving seeds and crops within the system. Based on household surveys and participatory observation, the study found that El Tablón, Sololá, Guatemala, had many characteristics of traditional Milpa, including intercropping of local landraces of maize (*Zea mays* L.), beans (*Phaseolus* spp.) and squash (*Cucurbita spp.*). The seeds are saved for generations and are usually not shared among neighbours, giving rise to high landrace diversity among the families. Fertiliser management includes the use of compost and manure. However, there was a widespread use of chemical fertilisers in the milpa system. The findings suggest that the Milpa system in El Tablón is dynamic and that farmers seek to conserve traditional landrace diversity while also adopting modern practices. The study shows that the Milpa system has an important cultural and personal value for smallholder farmers, who select seeds and crops based on both agronomic traits, and personal preferences. This highlights the need for further research and to promote *in situ* conservation, to secure agroecology and food sovereignty in Guatemala, and support long-term sustainability of the Milpa system.

Keywords: Agroecology, traditional agriculture, crop diversity, Guatemala, *in situ* conservation, intercropping, landrace diversity, maize-bean-squash, milpa

Contact Address: Kirstine Friis Lange, University of Copenhagen, Dept. of Food and Resource Economics, Thorvaldsensvej 40, 1871 Frederiksberg C, Denmark, e-mail: kirstine.lange@hotmail.com

Impact of maize plant residue on soil temperature dynamics in a dryland environment in Kenya

Juuso Tuure[1], Kevin Mganga[2], Matti Räsänen[3], Pirjo Mäkelä[1], Petri Pellikka[4], Laura Alakukku[1]

[1]*University of Helsinki, Dept. of Agricultural Sciences, Finland*

[2]*Utrecht University, Copernicus Institute of Sustainable Development, The Netherlands*

[3]*University of Helsinki, Dept. of Forest Sciences, Finland*

[4]*University of Helsinki, Dept. of Geosciences and Geography, Finland*

Soil temperatures are often high in dryland conditions. In cleared and tilled soils, increased temperatures contribute to accelerated rate of soil organic matter (SOM) decomposition, leading to increased CO_2 emissions and loss of soil fertility, and evaporation. Soil temperature behaviour depends on several dynamic parameters i.e. air temperature, precipitation, short wave radiation, soil moisture, and soil cover. Therefore, continuous measurements may be considered necessary to evaluate soil temperature dynamics under various treatments. Excluding growth of plants, the modification of soil thermal properties is reached through mulching, tillage practices and irrigation.

The recorded continuous soil and meteorological data were used to assess the impact of mulching on soil temperature in a dryland environment. Measurements were performed at the edge of a smallholder field in dry lowlands of Maktau, Kenya (3°25'33 S, 38°8'22, 1060 m asl). Soil temperature (Ts) and volumetric water content (θ) were measured continuously as vertical profiles (0–50 cm) during a two-year period (28/02/2016–26/02/2018). Meteorological parameters were recorded continuously on-site. The mulch was 1 cm thick maize stover corresponding to a mulching rate 5 t ha^{-1} (density 50 kg m^{-3}). The mulched period covered 28/02/2016–06/06/2016 (100 days). The mulch decomposed naturally. Initially, there was no vegetation on the soil surface and new vegetation growth was negligible during the experimental period.

Mulch reduced the diurnal fluctuation of measured Ts compared to bare soil. Daytime Ts peaks decreased below the mulch. The mulch also prevented nocturnal cooling of the soil. Ts decreasing effect was observed down to 30 cm. Reduced Ts fluctuation below mulch is suggested to be due to reduced shortwave radiation interception and increased heat capacity and conductance of soil due to conserved θ.

Plant residues find competing uses as forage and fuel among smallholder farmers in the study area, our results however, demonstrated that even a 1 cm thick maize stover layer clearly reduced the fluctuation of Ts down to 30 cm depth. Plant residue mulching can be recommended for dryland conditions similar to the studied site to reduce effects introduced by high Ts as well as conserve θ.

Keywords: Cooling effect, drought, mulch, smallholder

Contact Address: Juuso Tuure, University of Helsinki, Dept. of Agricultural Sciences, Koetilantie 5 P.O.Box 28, FI-00014 Helsinki, Finland, e-mail: juuso.tuure@helsinki.fi

In Iran's semi-arid regions, planting primed seeds is an efficient way to provide fodder under severe climatic conditions

Mahshid Soori[1], Nadia Kamali[1], Ali Noorifard[2], Saedeh Nateghi[1]

[1]*Research Inst. of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Rangeland Research Division, Iran*
[2]*University of Tehran, Management Department, Iran*

Due to the problems caused by the effects of climate change and excessive exploitation in the past, Iran's rangelands cannot provide enough animal fodder. Studies show that, in many regions of Iran, especially in arid and semi-arid regions, poor seed establishment is one of the common causes of low fodder plant yields. However, the need to use various techniques for improving and restoring rangeland species is now increasingly apparent due to the fact that a sizeable portion of ranchers in Iran's arid and semi-arid regions depend on rangeland feed.

Astragalus squarrosus Bunge is one of the native and adapted species in the sand fields of Iran, which is of great importance in terms of tolerance to severe climatic conditions and the value of fodder production for livestock, especially camels.

In order to investigate the effects of priming on seed germination and seedling growth, the experiment was conducted in split plots based on a randomised complete block design with five replications at Torud Research Farm in Semnan Province, Iran. This research was done on three ecotypes of *Astragalus squarrosus* and nine treatments. The distilled water was considered as the control treatment. So, seeds of different ecotypes, including Yazd, Kashan, and Semnan ecotypes of *A. squarrosus*, were primed separately under different treatments, including hydropriming, hormone priming (gibberellin hormone: 125 and 250 ppm, salicylic hormone: 100 and 200 mg L^{-1}, ascorbic hormone: 100 and 200 mM and osmopriming: potassium nitrate: 0.3 and 0.2 %). According to the findings of the current study, priming significantly affected *A. squarrosus* seed germination and yield. The Yazd ecotype under salicylic acid hormone 100 mg L^{-1} had the maximum performance in terms of yield and seed germination. In general, seed priming improves the yield and fodder production of *A. quarrosu*s. Therefore, further research under farmer conditions in Iran's semi-arid regions is necessary.

Keywords: Arid and semi-arid regions, *Astragalus squarrosus*

Contact Address: Mahshid Soori, Research Inst. of Forests and Rangelands, Agricultural Research Education and Extension Organization (AREEO), Rangeland Research Division, P.O. Box 13185-116, Tehran, Iran, e-mail: souri@rifr-ac.ir

Exploring the potential for improving crop water productivity to sustain future crop production in Egypt

Saher Ayyad[1], Poolad Karimi[2], Matthias Langensiepen[1], Lars Ribbe[3], Mathias Becker[1]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*

[2]*IHE Delft Inst. for Water Educ., Land and Water Management Dept., The Netherlands*

[3]*TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics, Germany*

Egypt is facing the challenge of sustaining food production for its ever-growing population, a situation that is likely to be exacerbated by climate change as well as by future water-related developments upstream the Nile. Most recent research suggests that Egypt's water deficit, the gap between renewable water resources and actual water use, as well as virtual water embedded in food imports will increase to sustain future food supply. Thus, this research investigates the potential of increasing productivity of major crops in Egypt, namely rice, maize, wheat, and clover (berseem), and consequently estimates future water and land resources needed to sustain supply of these crops by 2050. The study developed an approach using open-access gridded datasets to estimate three productivity indicators for the selected crops: (1) yield (= production/harvested area), (2) crop water productivity (CWP = yield/actual evapotranspiration), and (3) transpiration efficiency (TE = transpiration/actual evapotranspiration). Productivity indicators were analyzed, and potential improvements were estimated and used to develop scenarios for future demand for water and land to sustain production of the selected crops by 2050.

Based on the key findings of the current research, Egypt is expected to face challenges in satisfying its future demand for the four crops by 2050 given the substantial water and land required resources to produce sufficient quantities, following the average recent values of productivity indicators. However, based on the spatial-temporal analysis of yield, CWP, and TE, there are opportunities to increase productivity for all selected crops. Thus, quantities of required water and land by 2050 can be reduced by following high production efficiency. In light of these findings, the study proposes a few development strategies that could potentially enable the country to sustain crop supply for its future population. Challenges and opportunities towards realising these strategies are discussed. The methodological approach proposed herein can act as an operational tool for evidence-based policy development in water and agriculture.

Keywords: Development strategies, food security, remote sensing, scenario building, sustainable intensification, water management, water productivity, water-food nexus

Contact Address: Saher Ayyad, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Bonn, Germany, e-mail: saher.ayyad@uni-bonn.de

Alternate wetting and severe drying: A sustainable irrigation strategy for rice production in Burkina Faso?

Jean-Martial Johnson[1,2], Mathias Becker[1], J. P. Eric Kabore[2], Elliott Ronald Dossou-Yovo[3]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*
[2]*Centre National de la Recherche Scientifique et Technologique, INERA, Burkina Faso*
[3]*Africa Rice Center (AfricaRice), Côte d'Ivoire*

In the context of water scarcity and increasing fertiliser prices, reducing water input, while maintaining yield and nutrient use efficiency are of critical importance for sustainable production of irrigated rice. Alternate wetting and moderate drying irrigation (AWD15) (i.e., re-irrigation when the water level reaches 15 cm below the soil surface) proved to be an efficient water-saving technology in semi-arid zones of sub-Saharan Africa (SSA) as it allows for the reduction of water input without yield penalty. Alternate wetting and severe drying (AWD30) (i.e., re-irrigation when the water level reaches 30 cm below the soil surface) could further reduce the water input in comparison with farmers' irrigation practices (FP). However, the acute drying phases during its implementation may cause NO_3^-N losses through nitrification and denitrification and reduce the bio-availability of some key nutrients. What are the main potentials and risks of this technology for smallholder rice farmers in semi-arid zones of SSA? To answer this question, from 2019 to 2020, we conducted 33 on-farm field trials in Kou Valley, Burkina Faso, over three seasons and assessed yield, water productivity, nutrients use efficiency, and uptake under two different water management practices: AWD30 and FP. Compared with FP, AWD30 reduced irrigation water input by 37 % with no significant effects on grain yields (mean of 4.8 Mg ha^{-1}), thus increasing water productivity by 45 %. FP and AWD30 were comparable in terms of agronomic N, P, and K use efficiency and apparent N recovery, N, K uptakes, and Mn, Fe, and Zn tissue concentration. However, N content in straw, P and K contents in grain, and total P uptake were 11–16 % lower in AWD30 than in FP plots. In conclusion, AWD30 appears to be an effective strategy to save irrigation water without significant yield and N, P, and K use efficiency reduction. Therefore, AWD30 could be promoted as a substitute for farmers' irrigation practices in semi-arid zones of SSA. However, the observed P and K content reduction in grain points towards possible negative hidden impacts on grain quality and yield under certain conditions. Further studies could unravel the suitable domains for the implementation of AWD30.

Keywords: Agronomic use efficiency, drought, *Oryza* spp., water saving technology, West Africa, yield

Contact Address: Jean-Martial Johnson, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Karlrobert-Kreiten-Strasse 13, D-53115 Bonn, Germany, e-mail: j.johnson@uni-bonn.de

Assessment of cover crops implementation in mango and longan orchards in Battambang province, Cambodia

Sofia Marcon[1], Alessandra Giuliani[1], Florent Tivet[2], Veng Sar[3], Rosa Roeurn[4], Setha Rath[5]

[1]*Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*
[2]*French Agricultural Research Centre for International Development, France*
[3]*Conservation Agriculture Service Center (CASC), Cambodia*
[4]*National University of Battambang (NUBB), Cambodia*
[5]*Swisscontact, Cambodia*

After years of mono-cropping and farmland expansion, Cambodia is facing soil degradation, deforestation, and biodiversity loss. Conservation Agriculture (CA) could improve the Cambodian situation. Among the CA approaches, permanent soil organic cover, like cover crops, decreases soil erosion, suppresses pests and diseases, and increases yields. This study investigates about cover crops' opportunities and constraints in mango and longan orchards and farmers' knowledge and attitude towards this practice. A combination of qualitative and quantitative data collection was conducted in 2022 in Battambang province. Thirty-nine semi-structured household interviews were led in nine villages of Rattanak Mondoul and Banan districts, with CA-, CT- (conventional) and CT (CA*)- (previous CA, now CT) farmers. Two Focus Group Discussions were led in Sangha and Borun villages of Rattanak Mondoul districts. Key informant interviews and literature review completed the data gathering. The results showed that 21 out of 39 farmers does not know the definition of CA. Eighteen out of 18 CA- and CT (CA*)-farmers are satisfied with the application of cover crops and recommend CT-farmers to grow them. Thirteen out of 21 CT-farmers are willing to start growing cover crops in their orchards. The main reasons for farmers to start growing cover crops are weed presence, low soil fertility and high soil erosion in the orchards. Farmers have been noticing an improvement on their orchard and an increase in fruit yield since they started growing cover crops. According to farmers' perspective, more trainings and technical support about CA and cover crops are needed, which might also attract more farmers to these approaches.

Keywords: Cambodia, conservation agriculture, cover crops, extension, farm management, farmers' adoption, fruit trees, soil health

Contact Address: Sofia Marcon, Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), 6921 Vico Morcote, Switzerland, e-mail: s.marcon2912@gmail.com

ID 622

Trade-offs between nitrogen fixation and heavy metal(loid)s accumulation in a cassava-legume intercropping system on post-tin mining soils amended with local organic amendments

Rizki Maftukhah[1,2], Axel Mentler[1], Ngadisih Ngadisih[2], Murtiningrum Murtiningrum[2], Rosana Kral[3], Michael Gartner[4], Rebecca Hood-Nowotny[1], Katharina Keiblinger[1]

[1]*University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. of Soil Research, Dept. of Forest and Soil Sciences, Austria*

[2]*Universitas Gadjah Mada, Dept. of Agricultural and Biosystem Engineering, Indonesia*

[3]*University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. for Development Research, Dept. of Sustainable Agricultural System, Austria*

[4]*LVA GmbH, Lebensmittelversuchsanstalt (LVA), Austria*

Mining activities severely affect local ecosystems and threaten food security. In particular soils after tin mining on Bangka Island are highly nutrient deficient and characterised by low pH value. Remediation practices, however, are a viable way of reducing the negative impacts on post-mining lands.

In this study, we aimed to investigate the effect of locally available resources on heavy metal(loid)s (HMs) concentrations in crops and soil on a post-tin-mining site located on Bangka Island, Indonesia. Plots with five different soil amendments: (1) dolomite; (2) compost; (3) charcoal; combinations of (4) charcoal + compost; and (5) charcoal + sawdust; and control were established. An intercropping system with cassava and centrosema was employed, and HM concentrations in crops and soils were determined. In addition, the effects of different locally available soil amendments on the percentage of nitrogen derived from the atmosphere (%NDFA) and the amount of nitrogen fixation (N_2-fixation) in the cassava-legume intercropping system were investigated.

The highest amounts of N_2-fixation in centrosema were observed in combined treatment (charcoal + compost), which was influenced more by high shoot biomass production than %NDFA. Improved soil physicochemical properties had a positive impact on the shoot biomass of centrosema, resulting in a higher amount of N_2-fixation and N uptake values. Crop Pb, As, and Cd concentrations exceeded the international standard for maximum levels in food. The edible parts of cassava showed the highest Pb and As concentrations in the charcoal-only treatment. Furthermore, high Pb, As, and Cd concentrations in centrosema vegetative organs indicate a high risk for contamination

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Contact Address: Rizki Maftukhah, University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. of Soil Research, Dept. of Forest and Soil Sciences, Peter-Jordan-Straße 82, 1190 Vienna, Austria, e-mail: maftukhah.rizki@ugm.ac.id

of the human food supply chain, as these are used as cattle fodder.

Locally available organic soil amendments offer a potential solution for re-mediating post-tin mining soils by increasing N_2-fixation in centrosema when intercropped with cassava. However, due to the inherent high HM concentrations from their local origin, crop HMs can become accumulated in the edible parts of crops. In this study, the combined treatment of charcoal and compost showed the best compromise between improved nitrogen fixation and HMs concentration in a cassava-centrosema intercropping system on remediated post-tin mining soils.

Effect of irrigation efficiency enhancement on crop productivity and irrigation water availability under climate change in Nepal

Amit Kumar Basukala, Livia Rasche

University of Hamburg, Research Unit Sustainability and Climate Risks, Center for Earth System Research and Sustainability, Dept. of Earth System Sci., Germany

Crop production is predicted to be affected by climate change in terms of drought. That is the reason Nepal is expanding its irrigation facilities as adaptive measure in terms of water availability. However, water-efficient irrigation methods need to be used in the irrigation expansion due to the increasing water scarcity in Nepal. Therefore, in this study we assess the influence of three different irrigation efficiencies on potential crop productivity of rice, maize and wheat and on irrigation water savings under three climate change scenarios. The scenarios are based on SSP1–2.6 (low emissions due to strong mitigation), SSP3–7.0 (high emissions), and SSP5– 8.5 (extreme emissions/unmitigated) and are run with three general circulation models (GCMS) GFDL-ESM4, IPSL-CM6A-LR and MPI-ESM1–2-HR. The data are bias adjusted as part of the Coupled Model Intercomparison Project phase 6 (CMIP6) and acquired from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b) database. District and province level comparison of yields are carried out for the current time (2015 to 2022), near future (2023 to 2050), mid-century (2050 to 2075), and end century (2075 to 2100). The management scenarios are: (1) current management with an average irrigation efficiency of 30 %, (2) stress-triggered irrigation with efficiency 70 %, (3) stress-triggered irrigation with efficiency 50 %, and (4) stress-triggered irrigation with efficiency 30 %. For scenarios 2, 3 and 4 stress triggered mineral phosphorous and maximum annual 300 kg of mineral nitrogen per hectare is applied. We identified that on national scale yields can be increased by 1 t ha^{-1} for Maize, 0.5 t ha^{-1} for Rice and 1.5 t ha^{-1} for Wheat with an increase of irrigation efficiency from 30 % to 70 %. The results also showed the substantial water savings (up to 200 mm) could be attained if surface irrigation efficiency increases from the current value of 30 % to 70 %. The comparison showed the importance of efficient irrigation as a reliable adaptive measure for future climate change conditions.

Keywords: Climate change adaptation, irrigation efficiency, irrigation water management

Contact Address: Amit Kumar Basukala, University of Hamburg, Research Unit Sustainability and Climate Risks, Center for Earth System Research and Sustainability, Dept. of Earth System Sci., Riststr. 12, 22880 Wedel, Germany, e-mail: amit.basukala@uni-hamburg.de

Dose effect of organic matter on growth and biomass parameters of *Hibiscus sabdariffa* (L.) (Bissap) in the Fatick region

Saïd Chanfi Rehema, Oumar Sarr, Ndiabou Faye

Université Cheikh Anta Diop de Dakar, Dept. Biologie Végétale, Senegal

In Senegal, agriculture is a key sector of the economy, contributing around 8 % of the country's GDP. In addition to being an important economic lever, it makes a strong contribution to the country's social development through job creation, food security, and the fight against poverty. Thus, 60 to 70 % of the working population depends directly or indirectly on agricultural activities *Hibiscus sabdariffa* (L.) plays an important socio-economic role in the Sahel; through its calyxes, leaves and seeds it constitutes an important source of food and brings considerable income to producers. However, its production encounters enormous difficulties, notably due to poor soils and a lack of water, leading to a drop in yields. To alleviate this problem, growers resort to excessive use of chemical fertilisers which, in addition to the ecological and environmental problems they cause, are unable to maintain soil fertility levels. Hence the importance of this study, which aims to promote the use of organic residues to restore soil fertility. The aim is to contribute to sustainable productivity of Hibiscus sabdariffa through the use of horse dung in farming systems. Different doses were used to determine and compare their effects on the growth and fresh biomass of Hibiscus sabdariffa plants. The experimental set-up was a one-factor Fisher block with three treatments: 100 % dose, 50 % dose versus a control. Each fertiliser was applied to 2 kg, 1 kg and 0 kg of soil, respectively. Growth parameters were measured at regular dates and fresh biomass at the end of the trial. The results of this study were non-significant between the different doses. However, growth and biomass of *Hibiscus sabdariffa* were very satisfactory with DF100% followed by DF50% compared with the control (DF0%).

Contact Address: Oumar Sarr, Université Cheikh Anta Diop de Dakar, Dept. Biologie Végétale, Avenue Cheikh Anta Diop, 5005 Dakar, Senegal, e-mail: oumar9.sarr@ucad.edu.sn

Reusing pineapple residue to promote nutrient cycling and reduce GHG emissions in small-scale pineapple cultivation

Reena Macagga[1], Rinan Bayot[2], Pearl Sanchez[2], Mathias Hoffmann[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Germany*

[2]*University of the Philippines Los Baños, College of Agriculture and Food Science, Agricultural Systems Institute, Philippines*

The Philippines is one of the largest producers of pineapples in the world, with an annual production of over 2.8 million metric tons. However, pineapple production can also generate large amounts of pineapple residues (PR) that are usually not further utilised. They are often left to rot or burned mainly because of the high cost and labour needed for further utilisation, especially in small-scale cultivation. This practice creates challenges that are common globally, which include reducing the climate impact of cultivation while maintaining soil fertility and high resource efficiency. To address this, we hypothesise that reusing PR through soil incorporation in small-scale pineapple cultivation can promote nutrient cycling (C/N/P/K) and soil fertility while decreasing GHG emissions, particularly by increasing soil C sequestration. Additionally, we hypothesise that PR reuse can help reduce the use of mineral fertiliser, while still maintaining soil fertility and decreasing CO_2 emissions. To date, longer-term field studies regarding the effects of reusing PR in small-scale pineapple cultivation are still scarce. Using combined field and laboratory experiments, we aim to compare different PR reuse treatments against the common practice of using only mineral fertiliser and their effects on GHG (CO_2 and N_2O) emissions and nutrient cycling (C/N/P/K). Here, we present the results of our one-year field trial experiment on the effects of reusing PR on CO_2 emissions and biomass C/N/P/K performed in Calauan, Laguna, Philippines. We used the developed low-cost CO_2 and ET flux measurement device for manual closed chamber CO_2 exchange measurements of pineapple plants grown under various PR treatments. Additionally, soil and biomass sampling were done every three months to determine C/N/P/K change during the measurement period. This was also supplemented by non-destructive monitoring of biomass development using developed low-cost NDVI sensor. Lastly, the laboratory experiment was performed using developed low-cost incubation system to determine CO_2 and N_2O emissions of soil and PR treatments. Overall, we aim to provide evidence of the potential benefits of reusing PR and contribute to the utilisation of PR as a valuable resource that can help reduce waste and GHG emissions while enhancing nutrient efficiency for more sustainable small-scale cultivation practices.

Keywords: C sequestration, field trial, resource efficiency, soil fertility

Integration of CERES-maize modelling and remote sensing for crop condition and yield assessment in three agroecological zones in Kenya

Harison Kipkulei[1], Sonoko Dorothea Bellingrath-Kimura[1], Marcos Lana[2], Gohar Ghazaryan[1], Mark Boitt[3], Brian Rotich[4], Stefan Sieber[1]

[1]*Leibniz Centre for Agricultural Landscape Research (ZALF), Germany*
[2]*Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden*
[3]*Dedan Kimathi University of Technology, Inst. of Geomatics, GIS & Remote Sensing, Kenya*
[4]*Hungarian University of Agriculture and Life Sciences, Inst. of Environmental Science, Hungary*

Crop modelling and remote sensing (RS) integration are crucial for understanding crop conditions (CC) and agricultural production. In the present study, the DSSAT-CERES-Maize model was integrated with Sentinel^{-2} and moderate resolution imaging spectroradiometer (MODIS) RS data to analyse maize CC conditions and simulated yield in three agroecological zones (AEZ) in two counties of Kenya (Trans Nzoia and Uasin Gishu), with about 5425 km^2. AEZ I, II, and III correspond to humid, subhumid, and semihumid regions with high, moderate, and low moisture indexes, respectively. Sentinel^{-2} data was used to derive crop type extent maps, whereas MODIS data were used to map crop conditions via the enhanced vegetation index (EVI), normalised difference vegetation index (NDVI), and evaporative stress index (ESI).

The study showed that the RS CC exhibited high positive correlations with the simulated maize yield, especially at the peak season phenological stage. In particular, the ESI index demonstrated strong agreement with yield (r=0.94). Also, NDVI and EVI showed satisfactory performance, with correlations of r=0.89 and r=0.85, respectively. The response of the crop conditions at the AEZ level showed that AEZ I depict a strong relationship with the CC indicators compared to AEZ II and III. The analysis of the growing season influence showed that crop conditions and yield are strongly related between May and August (the vegetative-reproductive period in the study area). The study concludes that crop modelling approaches are important in exemplifying the relationships between crop conditions and maize production, especially in data-scarce landscapes. Integrating the assessment tools is important in monitoring agricultural landscapes, optimising agronomic management, and prior management of crop stressors to minimise/prevent yield losses.

Keywords: Ceres-maize, crop condition, DSSAT, remote sensing

Contact Address: Harison Kipkulei, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalderstraße 84, 15374 Müncheberg, Germany, e-mail: harison.kipkulei@zalf.de

Model-based climate change adaptational potential and productivity of some cowpea genotypes and its sensitivity to bias adjustment

Grace Adusei[1], Moses Kwame Aidoo[2], Amit Kumar Srivastava[1],
James Yaw Asibuo[3], Thomas Gaiser[1]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany*
[2]*Cocoa Research Institute of Ghana, Physiology and Biochemistry Division, Ghana*
[3]*Council for Scientific and Industrial Research, Crops Research Inst., Ghana*

Grain legumes are essential for the protein supply to an ever-growing population in Africa. However, little is known about the adaptive capacity of major grain legumes under future climatic change for the evaluation of climate change impact and adaptation. This study assessed the adaptation potential of some cowpea genotypes to future climate change in the moist (Kumasi-Ghana) and dry savannah (Ouagadougou-Burkina Faso) biomes of W-Africa based on a validated process-based cowpea crop model using the output of four GCMs (Global Circulation Models) for two Shared Socio-economic Pathways (SSPs i.e., ssp126 and 585). In addition, it assesses the sensitivity of the cowpea model to bias-corrections of the GCM outputs. In the comparison of future socio-economic pathways with historic time series, the use of bias-corrected climate model output slightly increased the rate of the phenological development of the genotypes in the future period except in Ouagadougou, in the ssp585 scenario. Without bias correction, this increase in the rate of phenological development in the future scenarios was less pronounced. With bias correction, the total aboveground biomass and yield of all genotypes were reduced in both shared socio-economic pathways. The change in the average water stress and phosphorous stress were genotype specific. Despite a general yield decline in both SSPs, the genotypes Asontem and GH6060 exhibited the best adaptational potential to future climate change in the moist and dry savannah biomes by the higher accumulation of total aboveground biomass, and higher yield, tolerance to high temperature as well as high water use and photosynthetic efficiency due to higher atmospheric CO_2 concentrations, despite faster phenological development

Keywords: Bias-correction, climate change, cowpea productivity, crop model, environmental stress

Contact Address: Grace Adusei, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Bonn, Germany, e-mail: aduseigrace@yahoo.com

Impact study of biochar and biomass amendment of *Gliricidia sepium* and shading on the productivity of agroforestry systems

AMOS BANINWAIN NAMBIMA DENE[1], THIERRY DÈHOUÉGNON HOUEHANOU[1], RODRIGUE V. CAO DIOGO[2]

[1]*University of Parakou, Laboratory of Ecology, Botany and Plant Biology, Benin*
[2]*University of Parakou, Dep. of Sci. and Techn. of Animal Prod. and Fisheries, Benin*

In recent decades, soils in West Africa have begun to gradually lose their fertility due to their misuse. This has led to a decline in agricultural productivity and yields. In order to achieve successful production, it is necessary to apply fertilisers (mineral or organic) rationally and use good production techniques. However, the economic constraints of households limit their adoption. This study was conducted in Cobly, a commune in the Atacora region of northwestern Benin. The average annual rainfall is 1,000 mm per year and is irregularly distributed during the rainy season. The objective of this study is to evaluate the effect of amendments and shading on millet productivity in agroforestry systems. A split-plot experimental design consisting of three blocks each associated with a species (*Parkia biglobosa*, *Vitellaria paradoxa*, *Lanea microcarpa*) with three replications. Four amendments (Control, gliricidia, biochar, gliricidia + biochar) are applied in concentric zones under and outside the tree. Analyses were performed with R 4.1.1 software. A linear mixed-effects model was used to identify determinants of growth and determinants of yield and a generalised mixed-effects model was used to assess variation in leaf number. Species, position, and treatment determined millet dry weight and millet grain weight. Biochar+Gliricidia treatment increased millet dry weight ($p < 0.001$). Only *Parkia biglobosa* has a shadow that negatively influences grain and dry weight of millet. The treatments increased millet height when the millet was out of the canopy ($p = 0.033$). Under the canopy, only Biochar+Gliricidia increased height.

Keywords: Amendment, Benin, shading, sorghum bicolor, traditional agroforestry systems

Contact Address: Amos Baninwain Nambima Dene, University of Parakou, Laboratory of Ecology, Botany and Plant Biology, Parakou, Benin, e-mail: amosnambima@gmail.com

Root-soil-contact influences on maize root growth, nutrient uptake, and nitrogen-cycling microorganisms in the rhizosphere

JANADI C. ILEPERUMA[1], ANNA S. WENDEL[1], SARA L. BAUKE[2], CLAUDIA KNIEF[1]

[1]University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Molecular Biology of the Rhizosphere, Germany

[2]University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Soil Science and Soil Ecology, Germany

The rhizosphere is enriched with microorganisms, including plant growth promoters and drivers of biogeochemical cycles. Root-soil interactions cover a wide range of biological and physicochemical processes with direct effects on plant growth. Therefore, approaching the rhizosphere in response to root-soil contact is an important strategy to improve crop growth and productivity to fulfil global food demand. Root hairs are an important root trait that ensures root-soil contact. Knowledge of the influence of root-soil contact on plant performance and microbial rhizosphere processes is limited. In this study, we explored the heterogeneity of the maize root system in response to reduced root-soil contact. Contact was modulated by artificial soil pores or the absence of root hairs. We determined the influences on root growth, nutrient uptake, and microbial abundance with a special focus on N-cycling microorganisms. Growth of the *Zea mays root hairless 3* (*rth3*) mutant was comparatively studied with its corresponding wild-type for 21 days in a climate chamber. Root-pore utilisation was characterised by endoscopic analysis. Shoot nutrient contents were quantified by CHNS analyzer and nitric acid digestion followed by flame AAS and ICP-OES analysis. A qPCR analysis targeting the *16S rRNA, amoA*, and *nirK* genes was carried out to quantify the abundance of bacteria, archaea, nitrifiers, and denitrifiers respectively. Root-growth behaviour inside the pores varied depending on the genotype and root type, though both genotypes tended to grow into the pores. Wild-type plants showed significantly higher shoot and root growth than the mutant. Artificial pores did not significantly affect nutrient uptake, suggesting compensation for missing root-soil contact by reducing biomass, while maintaining biomass nutrient levels. The wild-type harbored a higher abundance of bacteria and archaea in the rhizosphere than the root-hairless mutant. Likewise, the abundance of nitrifiers was significantly affected by root-soil contact, resulting in the highest abundance under complete root-soil contact. Both archaea and denitrifiers preferred the pore walls over the bulk soil, suggesting an anaerobic and nitrate-rich environment on the pore walls. Taken together, proper regulation of root-soil contact by reducing soil artificial porosity and selecting genotypes with higher root surface area is worth enhancing plant growth performance.

Keywords: Denitrifiers, microorganisms, nitrifiers, rhizosphere

Contact Address: Janadi C. Ileperuma, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Molecular Biology of the Rhizosphere, Bonn, Germany, e-mail: janadichamika21@gmail.com

Effect of long-term management on yield of dicotyledon plants in cotton systems

Ishwar Patidar[1], Akanksha Singh[2]

[1]bioRe Association, Agronomy, India
[2]Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

Organic agriculture is a promising solution to sustainably improve crop yields. For several crops, yield from organic farming have been recorded to be lower than yield from conventional farming. However, such data is context dependent and there is very little information on performance of organic systems in the tropics. Particularly, solid data on the benefits and drawbacks of organic agriculture in the tropics is still missing.

In 2007, we set up a long-term farming system comparison trials (LTE) for cotton systems in Madhya Pradesh India. Cotton is the main cash crop in our region and is grown in a two-year crop rotation. The other crops grown with cotton in our region are chickpea, wheat and soybean. In our field trials we are comparing the following treatments: (i) organic, (ii) bio dynamic, (iii) conventional, and (iv) BT conventional (genetically modified) cotton. We have been taking data on multiple parameters such as crop yields, soil nutrients, soil microbial properties and system profitability

Our data indicates that with good management organic systems can become more sustainable than conventional systems both economically and ecologically. Multiple indicators in our trials show this; the performance of crops has improved over the years, reducing the profitability gap between organic and conventional farming systems. In addition, positive impacts on soil fertility indicators (e.g., soil organic carbon) are detectable after 10–12 years in our organic LTE systems. We have also recorded our organic systems to harbour higher biodiversity. Despite our positive results, adaption of best management practices by the farmers remains one of the biggest challenges.

We need more studies on long-term cumulative effect of system approaches on fertility, health and the productive capacity of agricultural lands in conventional and organic farming systems. We need to understand what extent system approaches can enhance the resilience of cotton systems.

Keywords: Chickpea, cotton, crop rotation, dicotyledon, long term system, organic, soybean, treatment, wheat

Contact Address: Ishwar Patidar, bioRe Association, Agronomy, 5th mile stone mandleshwar road kasrawad khargone mp, 451228 Kasrawad, khargone, India, e-mail: ishwar.biore@gmail.com

Functional biodiversity in organic and conventional cotton farming systems

Christelle Ledroit[1], Barbara Smith[2], Gurbir Bhullar[3]

[1]*FiBL - Research Institute of Organic Agriculture, India*

[2]*Coventry University, Agroecology, United Kingdom*

[3]*Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*

Farmland Biodiversity performs a variety of ecosystem services which are directly linked to food production and sustainable agriculture. The crucial role of ecosystem services has been understudied, especially in the tropics. Cotton is one of the most polluting crops in the world, as it requires high inputs of both pesticides and fertilisers. Globally, India is the second-highest producer of cotton, yet it is also the country with one of the lowest yields per hectare. In 2002, India introduced Bt cotton, it holds genes from *Bacillus thuringiensis* that make the plant resistant to the main cotton pest, the American bollworm. Following this introduction, an outbreak of sucking pests such as jassids and aphids has been observed in these systems. On one side, pesticides which were used to fight the bollworms decreased, but on the other side, the use of sprayed pesticides increased. Studies have shown that sprayed pesticides affect pests as well as non-targeting arthropods. In India, the majority of entomological research on cotton systems has been focused on the pest community and the resistance they have built up over time. There is a strong need to be able to compare the impact of these farming systems on functional biodiversity. My study has been exploring biodiversity indicators present in the soil, above ground and on the cotton canopy. The study has been done on a long-term cotton trial in Madhya Pradesh, comparing four different systems: Bt-conventional, conventional, organic and Biodynamic as well as on farmer's fields, comparing Bt-conventional and organic systems. The results have shown a higher diversity in the organic systems above and below ground. The results from the long-term trial have shown no significant difference between the Bt-conventional and non-Bt-conventional. During this presentation, I will outline the long-term effects of pesticides (as well as fertilisers) on the functional biodiversity in the above-mentioned cotton systems.

Keywords: Aboveground, belowground, biodynamic, Bt-conventional, cotton, functional biodiversity, organic

Contact Address: Christelle Ledroit, FiBL - Research Institute of Organic Agriculture, House n1217 grande carona, 403523 Aldona, India, e-mail: christelle.ledroit@outlook.com

Effect of conventional and organic practices on cotton quality parameters compared across 15 years

Bhupendra Singh Sisodia[1], Akanksha Singh[2], Eva Goldmann[2]

[1]bioRe Association, Agronomy, India

[2]Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

Cotton is the most widely used fibre crop and quality parameters such as fibre length are crucial for successful processing. These quality parameters can be influenced by a variety of factors, such as nutrient supply to the plant and varieties used. Establishing a correlation between these influential factors and the quality parameters of cotton can help improve the production process and enable farmers to earn more income from their cotton production.

This study aimed to assess product quality data from a long-term farming systems comparison trial under semi-arid conditions in central India in regard to different management regimes. The trial has been running since 2007, comparing biodynamic, organic, and conventional with GM and without GM cotton management. All treatments include a two-year crop rotation which is first-year cotton-wheat/chickpea and second-year soybean-wheat. To assess fibre quality, we took sampled plants for ginning and subsequent lab testing for quality parameters like fibre staple length, fibre fineness, maturity index, micronaire etc.

Results show that no significant difference in quality parameters like fibre length, fibre fineness, short fibre index, maturity index in both the systems even less percentage of nitrogen was provided in an organic system.

The results considering which factors are the most important and which are of lesser importance provide some insight into changes in management effect on lint yield and fibre quality and provide some basis for future investment in research. This bears relevance to stakeholders in the cotton industry including both Indian and international cotton merchants, ginners, spinners, textile mills and commodity exchange.

Keywords: Biodynamic, conventional, cotton, crop rotation, organic, quality parameter, system

Contact Address: Bhupendra Singh Sisodia, bioRe Association, Agronomy, 5th km mile stone mandleshwar road, 451228 Kasrawad, India, e-mail: biore.bhupendra@gmail.com

Opportunities of mine reclamation areas for food crops plantation: Case study of coffee plants in former limestone mining

Tedi Yunanto

Ministry of Energy and Mineral Resources, Bandung Polytechnic of Energy and Mining, Indonesia

Reclamation activities must be carried out after mining operations are completed. Mine reclamation areas, such as limestone mines, can be used as food crops plantation e.g. coffee. However, limestone dust affect the soil physical, chemical and biological properties, which will affect the coffee growth. Therefore, to increase the coffee growth, arbuscular mycorrhiza fungi (AMF) was introduced. The purpose of this study was to determine the effect of limestone dust covering former mines and different doses of AMF on coffee growth. The study was conducted using a RCBD method. The study area was divided into several blocks consisting of soil without lime dust, 0–2.5 cm and 0–5 cm dust cover. The blocks were treated with 10 g, 15 g and 20 g AMF with 5 replications each. Inorganic NPK fertiliser was given every month (till 5 month) to all treatments with successive 10 g/seedling, 20 g/seedling, 30 g/seedling, 40 g/seedling and 50 g/seedling for each month. Parameters observed were plant height, plant diameter, and number of leaves. The research results show that limestone dust affects soil conditions such as silt, clay, pH, organic C, bulk density, and C/N ratio. In addition, limestone dust affected plant height and number of leaves of coffee seedlings compared to those grown in areas without dust. The influence of the amount of AMF was significant ($p < 0.05$) and tended to increase the height and diameter parameters of the coffee seedlings. The mean height of coffee seedlings in the 10 g treatment was 23.09 cm, while 15 g = 26.73 cm and 20 g = 25.59 cm. While the mean diameter for the 10 g = 3.78 mm, 15 g = 3.94 mm, and 20 g = 4.53 mm, however, the difference in the doses of AMF was proven to significantly ($p < 0.05$) decrease the number of leaves, namely 10 g = 10 leaves, 15 g = 9.5 leaves, and 20 g = 8 leaves. This study shows that coffee plants can be planted in mine reclamation areas, but further research is needed regarding the quantity and quality of coffee beans produced.

Keywords: Coffee, limestone dust, mine reclamation, mycorrhizal biofertiliser, soil

Contact Address: Tedi Yunanto, Ministry of Energy and Mineral Resources, Bandung Polytechnic of Energy and Mining, Jl. Jenderal Sudirman No. 623, 40211 Bandung, Indonesia, e-mail: genom.tedi@gmail.com

Optimisation of micropropagation protocol for mass multiplication of hybrid coffee (*Coffea arabica* L.) cultivars of Ethiopia

Habtamu Seyoum Aragaw, Elias Gebremariam

Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Plant Biotechnology Department, Ethiopia

Hybrid technologies were expected to revolutionise the Ethiopian coffee sector through the exploitation of heterosis conserved in the F1 hybrids. However, due to a lack of efficient propagation methods, these high-yielding cultivars were not disseminated to growers. Nevertheless, large quantities of planting materials of elite varieties can be multiplied by tissue culture methods once successful optimisation of conditions is completed *in vitro*. We followed an indirect somatic embryogenesis approach and optimised an efficient and reproducible protocol to propagate F1 hybrid varieties. We also applied a simple and cost-effective approach to sterilizing the leaf and obtained an 80–90 % clean explant that produces a callus. Using various combinations of PGRs, mainly auxin and cytokinin, in addition to MS medium, vitamins, amino acids, carbon sources, and organic supplements, on average 401 somatic embryos per explant (i.e., from a 1 cm^2 leaf disc) were obtained. The result achieved after several years of efforts may be a breakthrough for the coffee sector if existing capacity improves on an industrial scale and smallholder producers have access to high-quality TC-raised planting materials.

Keywords: Coffee, F1 Hybrids, micropropagation, somatic embryogenesis

Contact Address: Habtamu Seyoum Aragaw, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, Plant Biotechnology Department, P.O. Box 192, Jima, Ethiopia, e-mail: htito2050@gmail.com

ID 614

Pest, diseases and control options

Online posters

Transformation and intensification of food crop production in Africa in light of increasing threats from pests and diseases

Stephan Winter, Samar Sheat

Leibniz Institute DSMZ, German Collection of Microorganisms and Cell Cultures GmbH, Germany

Pests and diseases present a major constraint to the production of food in Africa, threatening horticultural and agricultural crops alike and causing severe losses of harvest and income. To effectively respond to the increasing demand for food requires a transformation of the food production systems encompassing all components of the systems.

Plant health, starts with healthy and productive propagules. Because in Africa, most of planting materials are traded (exchanged) through informal systems, diseases are spread through human activities. The cassava virus diseases, Fusarium oxysporum TR4, and banana bunchy top virus in banana provide ample evidence for this uncontrolled threat. Seed health, even of commercial seeds, is not given the highest priority and outbreaks of virus diseases in soybean, groundnut and maize can be traced to seed-borne pathogens or, the use of contaminated seed (MLN in maize, ToBRFV in tomato). Pest populations driven by changing weather patterns cause direct damage (Tuta absoluta) or, indirectly, from the spread of virus diseases (Bemisia tabaci) that can destroy cultivation of crops like tomato, cassava or cotton. Healthy seeds and planting materials are the prerequisite for a productive crop and resistant varieties, the main element of disease management in field production systems. However, for many crops resistant, cultivars are not available and crop management in open fields is merely a sequence of chemical control interventions. To mitigate the impact of pests (and the diseases they spread) to horticultural crops, a transition from field production to protective cultivation in screenhouses, as already seen in few African countries, is likely the only option to guarantee a comprehensive crop management following the guiding principles of "good horticulture practices". Under protective cultivation, a framework of measures that include bio-control agents and the sensitive application of pesticides can be applied that, in field production, are not feasible. Challenges and opportunities for African farmers will be highlighted.

Keywords: Crop management, emerging disease threats, plant health

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Contact Address: Stephan Winter, Leibniz Institute DSMZ, German Collection of Microorganisms and Cell Cultures GmbH, Inhoffenstraße 7B, 38124 Braunschweig, Germany, e-mail: stephan.winter@dsmz.de

ID 603

Distribution, incidence and severity of *Fusarium wilt* on cotton in Benin

Tinon Nehal Djaouga Mamadou[1], Hugues Kossi Baimey[2],
Bonaventure Cohovi Ahohuendo[1]

[1]*University of Abomey-Calavi, Fac. of Agricultural Sciences, Benin*
[2]*University of Parakou, Fac. of Agronomy, Benin*

Cotton cultivation contributes 46 % of Benin foreign exchange earnings. It is cultivated by 325,000 farmers and plays a major role in sustaining food security in the country because it serves as a means through which fertilisers are provided to other food crops such as maize, sorghum and rice. However, very little attention has often been paid to diseases and other pests that constitute a limiting factor in cotton production; especially diseases such as fusariosis caused by *Fusarium oxysporum* f.sp. *vasinfectum* which is one of the most threating factors in large cotton production area. A field survey was conducted in 2022 in 50 sites of 15 districts of all cotton production areas in Benin to access *Fusarium* infestation levels. At least two sites were surveyed per district and on each site, 20 plants were inspected and evaluated randomly along the two diagonals of a cotton field, respectively for the incidence and the severity of the disease. The results showed that *Fusarium wilt* was present in 11 out of 50 sites. The highest means for incidence (31,25 %) and severity (13,25 %) were observed in the agroecological zone four with the maximum incidence in the district of Dassa (48,33 %). The agroecological zone two recorded the lowest incidence (0,27 %) and severity (0,16 %). Across the different cotton varieties in use, the variety OKP 768 was the most susceptible showing the highest incidence (17,03 %) and severity (9,77 %). Finally, the disease is present in Benin with various rate of incidence and severity which are high in the centre part of the country. There is an urgent need of deep understanding of the phenomena as it will contributes to a proper management of the disease that can quickly spread.

Keywords: Benin, cotton, *Fusarium oxysporum*, incidence, severity

Contact Address: Tinon Nehal Djaouga Mamadou, University of Abomey-Calavi, Fac. of Agricultural Sciences, Abomey-Calavi, Benin, e-mail: tinondjaouga@gmail.com

Mobilizing natural enemies for sustainable plant pests and diseases management

James Mwangi, Ruth Kariuki, Eric Kuria, Eunice Githae

Chuka University, Biological Sciences, Kenya

Smallholder farmers contribute approx. 70 % of food supply in Africa. They produce for their subsistence use and sell the surplus in the local market. These farmers make a substantial contribution to sustainable food security in the global south. Their capacity to upscale production is however constrained by shrinking land sizes, high cost of agricultural inputs, impact of climate change as well as damage by pest and disease. Majority of smallholder farmers rely on cultural techniques to keep pests and diseases below economic threshold level. However, persistent use of agricultural chemicals predispose them to risks associated with mishandling and misuse of pesticides. Besides, consumers are exposed to adverse effects of pesticides due to chemical residue in food. To boost food production, there is need for ecologically sustainable pest control methods to minimise agri-pollution, boost productivity and promote biodiversity in Africa. Such methods include use of natural enemies (biocontrol agents) for pests and diseases management. We carried out a survey for potential fungal microbes that parasitize and destroy plant nematode eggs for use as biocontrol agent against potato cyst nematodes (PCN) *Globodera rostochiensis* and *G. pallida* in Kenya. Soil samples were collected from smallholder farms in six leading potato-producing counties of Kenya. The samples were processed in the laboratory and PCN cysts extracted using floatation techniques in Fenwick can. Extracted cysts and eggs were visually examined for fungal infestation. Those showing symptoms of fungal infestation were selected, culture on PDA media and incubated at room temperature, fungal growth were monitored for several days. Fungal colonies were sub-cultured to generate pure culture for further analysis. Ninety-five percent of the soil samples tested positive for PCN infestation. However, the prevalence of PCN in the six counties differed significantly ($p < 0.05$). Fifteen fungal isolates were found associating with PCN cysts and eggs. Characterisation of these fungal isolates is under way. The efficacy of these isolates is being tested *in vitro* and *in vivo* before being processed for use as biocontrol agent again PCN. If successful, the natural enemy will significantly contribute in reduction on use of synthetic chemicals in nematode management besides boosting potato production.

Keywords: Biocontrol, *Globodera* spp., nematophagous fungi

Screening cassava for resistance against cassava mosaic and cassava brown streak viruses using a precise and rapid high throughput workflow

Samar Sheat, Stephan Winter

Leibniz Institute DSMZ, German Collection of Microorganisms and Cell Cultures GmbH, Germany

Growing cassava in Africa requires resistance against the viruses causing cassava mosaic disease (CMD) and the viruses causing cassava brown streak disease (CBSD). Breeding cassava for resistance against viruses requires the sources of resistance, readily flowering genotypes to produce viable crosses, seeds, and most importantly, a straightforward screening process. Screening for resistance against mosaic viruses can be achieved by planting seedlings into virus hotspots because infections and disease spread with viruliferous whiteflies are guaranteed. Symptoms become readily visible, and scoring for disease incidence and severity allows the selection of resistant candidates already during the first planting season. In contrast, screening for resistance against cassava brown streak viruses is cumbersome because of the unpredictable transmission by whiteflies and the slow plant infection processes that are often not associated with distinct leaf symptoms. Thus, only the assessment of root necrosis which is done at the end of the growing cycle can serve as an indicator for plant resistance/tolerance. The selection of promising candidates thus is associated with high uncertainties from the erratic virus infections. We have developed a high throughput virus screening workflow for cassava resistance screening by which cassava seedlings pass through an intensive and precise virus infection routine after which resistance against mosaic and brown streak viruses can be assessed with high accuracy and, in less than nine months - from seedling infection to a final verdict. Components of the tactics are; effective virus infections, reduced biological repeats, and increased accuracy; susceptible sensitive lines are eliminated early to conduct detailed virus studies with pre-selected lines only. The developed protocol shifts resistance evaluation from the field to the nursery, replacing the erroneous and lengthy infection and screening process with a method of precision and speed.

Keywords: CBSD, CMD, disease tolerance, dual virus resistance, plant immunity, precise virus screening, resistant cassava

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Contact Address: Samar Sheat, Leibniz Institute DSMZ - German Collection of Microorganisms and Cell Cultures, Plant Virus Department, Inhoffenstraße 7b, 38124 Braunschweig, Germany, e-mail: samar.sheat@dsmz.de

Uncovering the genetic diversity of *Hemileia vastatrix* in three coffee-producing areas in Guatemala and its implications for resistance of coffee varieties

José Alejandro Ruiz-Chután[1], Marie Kalousová[1], Julio Ernesto Berdúo-Sandoval[2], Carlos Villanueva-González[3], Amílcar Sánchez-Pérez[2], Nelson Pérez[4], Eder González[4], Bohdan Lojka[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Czech Republic*

[2]*Universidad de San Carlos de Guatemala, Facultad de Agronomía, Guatemala*

[3]*Universidad Rafael Landívar, Facultad de Ciencias Ambientales y Agrícolas, Guatemala*

[4]*Asociación Nacional del Café, Centro de Investigación en Café, Guatemala*

Coffee rust, caused by the fungus *Hemileia vastatrix*, is the leading disease that attacks the crop worldwide. One of the strategies for controlling the disease is the genetic factor, developed through breeding programmes that result in coffee genotypes resistant to the pathogen. However, to make the best use of this factor, it is essential to know the molecular factor of the pathogen. Despite the importance of coffee cultivation for Guatemala, there is no study of the pathogen's population structure, genetic diversity, and haplotypic diversity. This study evaluated the genetic diversity and population structure of *H. vastatrix* fungal populations in three coffee-producing departments in Guatemala using 17 microsatellite polymorphic markers and ITS. Between 2 and 11 alleles per locus were observed, with a mean of 5.22. The Shannon diversity index, nucleotide, and haplotypic diversity showed values of 0.86, 0.0051, and 0.985, respectively. High within-population variation was observed (92 %). In addition, high levels of gene flow between populations were found, suggesting low genetic differentiation ($F_{st} = 0.024$) between populations. The haplotype network showed that *H. vastatrix* isolates behave as a large population without defined differentiation, in which ancient haplotypes were detected from which new variants of the fungus emerged. The Tajima test showed that the populations of *H. vastatrix* are undergoing an expansion process. In general, *H. vastatrix* populations in Guatemala are highly variable, and genetic variation is widely distributed in all the departments studied. It was determined that the haplotypic diversity of *H. vastatrix* may influence the resistance of coffee cultivars. The severity tests of *H. vastatrix* exhibited a statistically significant difference ($p < 0.001$) in the area under the disease progress curve (AUDPC) among the eight varieties evaluated. Still, the interaction between the pathogen and the plant is complex, and other environmental factors may also influence resistance.

Keywords: Coffee leaf rust, genetic diversity, haplotype network, ITS, microsatellites

Effect of sowing date of faba bean (*Vicia faba* L) cultivars on *Orobanche crenata* seed bank and faba bean production

Esmat Hegazi[1], Wedad E. Khafagi[2], A Abou Zied[3]

[1]*Alexandria University, Dept. of Entomology, Egypt*
[2]*Plant Protection Research Institute, Biological Control, Egypt*
[3]*Field Crops Research Institute, Food Legumes Research Department, Egypt*

The broomrape, *Orobanche crenata* Forsk (Orobanchaceae) is an annual parasitic weed. It is a serious parasitic weed causing considerable losses in many major crops including faba bean (*Vicia faba* L.). In Egypt, losses due to *O. crenata* parasitism may reach 40 to 100 %. Several methods have been used for controlling *O. crenata* but without success. Some of these methods are unfeasible and costly. Little is known about the effect of different control strategies on *O. crenata*. Sowing date seems to be one of the potential solutions for controlling *O. crenata*. In this work we studied the effect of sowing dates on both the degree of infection by *O. crenata* and the pod yield of faba bean using resistant (Giza 843) and susceptible (Nubaria 1) faba bean cultivars in naturally *Orobanche* infested soil. The results demonstrated that, late sowing (3 weeks after normal sowing date) reduced significantly the number of emerged *O. crenata* shoots for both the resistant and the susceptible cultivars . Pod yield increased significantly on late sowing especially for the resistant Giza 843 cultivar (115.2 kg per plot) which produces much higher pod yield than the susceptible Nubaria 1 cultivar (86.4 kg per plot). This can be explained by the reduced number and dry weight of *O. crenata* attachments and a slight decrease in shoot dry weight of the resistant cultivar. So, combining both resistant cultivar with late sowing could be a useful tool as a part of an integrated strategy to control *O. crenata* in faba bean fields.

Keywords: Faba been cultivars, *Orobanche crenata* seed bank, Faba bean production, sowing date

Contact Address: Esmat Hegazi, Alexandria University, Dept. of Entomology, Aflatoun Str., 21545 Alexandria, Egypt, e-mail: eshegazi@hotmail.com

Fatty acids as sustainable biorationals for weed control

Farimah Asadi[1], Thorstan Kraska[1], Michael Petry[2]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany*

[2]*PETRYmade Oberflächentechnik, Meckenheim, Germany*

As the global population continues to grow, food production must increase sustainably. This requires enhancing crop yields while reducing the environmental impact of agricultural practices. Weeds are a significant biotic constraint to food production as they compete with crops, reducing agricultural output and increasing external costs. Synthetic herbicides have been the primary method for weed control, but their harmful environmental effects require finding sustainable alternatives. Fatty acid compounds, derived primarily from glyceridic plant oils, are one such alternative. These natural products offer low ecotoxicological side effects and high biodegradability, making them a promising alternative to synthetic herbicides. Pelargonic acid is one fatty acid which is already on the market. This study aimed to evaluate the herbicidal efficacy of an oil-in-water-emulsion preparation containing various fatty acid compounds separately and in mixtures. The greenhouse experiments were conducted on green beans, which are sensitive to herbicides, to determine the phytotoxic potential of the compounds. The results showed that pelargonic acid had high phytotoxic effects on green beans at the level of 1 % and more, while caprylic acid was an effective post-emergence herbicide even at low concentrations of 0.5 %. Even at the lowest concentration of 0.1 %, both compounds exhibited signs of damage, and as the concentration increased, death occurred. Linseed oil (containing linolenic acid as the main fatty acid) also showed potential to exert different levels of phytotoxicity but not as strong as other compounds. The effect strongly depends on the type of fatty acid (chain length). From the experiments it could be shown that the effects of the treatments were dose-dependent, with higher concentrations leading to greater levels of damage and eventual death. Overall, the study's findings highlight the potential of fatty acid compounds as biorational post-emergence herbicides in sustainable weed management strategies. Incorporating these natural products into integrated weed management programmes could contribute to producing crops subjected to less stress in a sustainable manner, promoting sustainable food production to meet the demands of the growing population.

Keywords: Integrated weed management, sustainable agriculture

Contact Address: Farimah Asadi, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sciences, Adenauerallee 170, 53113 Bonn, Germany, e-mail: s7faasad@uni-bonn.de

Effects of microbial inoculants on growth and salinity tolerance of hydroponically-grown tomatoes

Graham Giesting, Jörn Germer, Folkard Asch

*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (*Hans-Ruthenberg-Institute*), Germany*

The relationships of plants with soil-living bacteria and fungi are known to potentiate plants' resistance to diseases, ameliorate plants' stresses and stress responses, and promote plants' growth. Hydroponic production has increased in prevalence all over the world, as a production approach which enables greater control for growers over their plants' environments and more optimal use of scarce resources. The microbial communities with which plants interact in hydroponic environments vary from those in soil in profusion and variety, but microbes are nonetheless present there and can interact with plants, and their effects in these production systems are largely uninvestigated and untapped.

To assess the effect of different microbiota in conferring salinity resistance to tomato (*Solanum lycopersicum*, var. Sweeterno), plants were inoculated with *Bacillus megaterium* Ni-5-SO-11, *Pseudomonas brassicacaerum* 3Re2–7, and *Trichoderma harzianum* DSM 32006 in a basic hydroponic system. Tomato seedlings were treated with each these three inoculants, with and without 60 mM of NaCl, grown for 2 weeks in 2.5 l buckets with 50 % INTEGAR nutrient solution oxygenated via a bubbling air hose, then harvested, measuring biomass, SPAD, leaf area, and tissue ion concentration. Significant differences were found between inoculant treatments and controls in biomass and biomass distribution, SPAD, leaf area, and tissue ion concentrations. Endophytic bacteria were found to induce more consistent and positive responses than fungi, whose mycorrhizae did not thrive in solution and who had widely variable – but generally detrimental – effects on biomass, SPAD, and root length and health. These findings suggest that (certain of) the studied inoculants may boost plant performance in a hydroponic setting.

Growth promotion of hydroponically grown plants by microbes could potentially provide significant benefits. This would occur in a physical and biological environment where the makeup of the microbial community can be directly controlled, e.g. via aqueous inoculation of plants with beneficial inoculation over the full submerged root surface. The plants in this study were harvested at 18 days. Although this makes yield-effect predictions more abstract, this approach could be used as a screening protocol for candidate PGP microbial strains.

Keywords: Hydroponics, microbial innoculant, salinity, *Solanum lycopersicum*

Contact Address: Graham Giesting, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: ggiesting@gmail.com

Inhibitory activity of bacterial lipopeptides against *Fusarium oxysporum* f.sp. *strigae*

Mekuria Wolde Assena[1], Jens Pfannstiel[2], Frank Rasche[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*University of Hohenheim, Core Facility Hohenheim, Mass Spectrometry Unit, Germany*

This study investigated the impact of bacterial cyclic lipopeptides (LP; surfactins, iturins, fengycins) on microbial interactions in the plant endosphere. The objective was to investigate whether the presence of bacteria inhibits fungal growth and whether this inhibition is due to the release of bacterial metabolites, particularly LP. The study employed selected endophytic bacterial strains with known plant-growth promoting potential that were cultured in the presence of *Fusarium oxysporum* f.sp. *strigae* (*Fos*), which was applied as the model fungal organism. The extracellular metabolome of tested bacteria, with a focus on LP, was characterised, and the inhibitory effect of bacterial LP on fungal growth was investigated. The results showed that *Bacillus velezensis* GB03 and FZB42, as well as *B. subtilis* BSn5 exhibited the strongest antagonism against *Fos*, while *Paraburkholderia phytofirmans* PsJN had a slight stimulatory effect. Crude LP from strains GB03 and FZB42 had the strongest inhibitory effect on *Fos*, with a significant inhibition of spore germination and damage to the hyphal structure. Liquid chromatography tandem mass spectrometry revealed the production of several variants of iturin, fengycin, and surfactin LP families from strains GB03, FZB42, and BSn5, with varying intensity. Using plate cultures, bacillomycin D fractions were detected in higher abundance in strains GB03, FZB42, and BSn5 in the presence of *Fos*. Additionally, the presence of *Fos* in dual plate culture triggered an increase in bacillomycin D production from the *Bacillus* strains, possibly through activation of signaling molecules. It was also suggested that fungal metabolites produced by *Fos* in dual culture might have triggered LP production by bacteria. The study clearly demonstrated the potent antagonistic effect of certain *Bacillus* strains, including *Bacillus* sp. GB03, FZB42, and BSn5, on *Fos* development. Conversely, we found that *P. phytofirmans* PsJN promoted the development of *Fos*. Our findings emphasise the crucial role of microbial interactions in shaping the co-existence of microbial assemblages in plant endospheres.

Keywords: Bacillomycin D, biological control, co-inoculation, lipopeptide abundance, microbial interaction

Contact Address: Mekuria Wolde Assena, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr. 13, 70593 Stuttgart Stuttgart, Germany, e-mail: mekuriawolde.assena@uni-hohenheim.de

ID 427

Protecting organic cotton: Biopesticides tested against the American bollworm

Dharmendra Patel[1,2], Akanksha Singh[2], Eva Goldmann[2]

[1]*bioRe Association, Entomology, India*
[2]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*

One of the most widely used fiber crops in the world, cotton is utilised in manufacturing clothing and other goods. Its production is highly affected by the American bollworm pest, *Helicoverpa armigera*. To fight off the attacks of *H. armigera*, GMO Bt-cotton was designed, which now dominates India's cotton production. In India, around 90 % of the total cotton production is sourced from Bt Cotton. However, as GMO crops are not allowed in organic farming the attacks of the American bollworm remain a major threat to organic cotton production. At our study site in Madhya Pradesh in central India, we tested different biopesticides on the American bollworm in organic cotton field trials. Three commercially available biopesticides containing the a) Nuclear polyhedrosis virus, b) *Bacillus thuringiensis*, and c) *Metarhizium rileyi* were evaluated and compared with the control, which was not treated against pest attacks. The experiment included four replications in 2021 and 2022. We monitored the pest occurrence and started applying the treatments when the economic threshold level was reached. We counted the number of larvae and eggs of the American bollworm on the cotton plants in regular scouting. In both years, the number of *H. armigera* on the cotton plants was significantly reduced compared to the control. All treated plots had significantly fewer damaged balls when compared to the controls. However, no significant effect on yield could be found. Further research is needed to evaluate the effectiveness of commercially available biopesticide products in laboratory tests. Furthermore, we envisage insect ecology studies to better understand the pest dynamics affecting organic cotton production.

Keywords: Biopesticides on American bollworms

Contact Address: Dharmendra Patel, bioRe Association, Entomology, 5th km mile stone mandleshawar road kasrawad, 4511228 Kasrawad, India, e-mail: biore.dharmendra@gmail.com

Reaction of common bean genotypes to plant parasitic nematodes

ADRIANE WENDLAND, ENDERSON FERREIRA, WALDIR PEREIRA DIAS,
IVANI DE OLIVEIRA NEGRÃO LOPES

Embrapa - Brazilian Agricultural Research Company, Brazil

Brazil is the world's largest producer of common bean (*Phaseolus vulgaris* L.), a basic dietary protein food source in the diet of the Brazilian. The consumer choice regarding grain colour, grain type, and culinary quality varies regionally, being the carioca grains (pinto bean) the type that dominates 70 % of the common bean market. The use of resistant cultivars is the most efficient strategy to control the nematode population, besides being appropriate to the producer. Nevertheless, few common bean genotypes that could serve as sources of resistance to nematodes have been identified in Brazil. These strategie being frequently the easiest and least expensive approach that can be adopted by farmers. However, in the case of the common bean in Brazil, few sources of resistance have been identified so far. Thus, this study was conducted to assess the reaction of 81 common bean genotypes to the most abundant and harmful plant parasitic nematode species in brazilian crop fields: *Meloidogyne incognita* race 3, *Meloidogyne javanica*, *Pratylenchus brachyurus*, and *Heterodera glycines* race 3. We evaluated the reactions of the genotypes to the nematode species individually, by computing their relative reproduction rates to a susceptibility standard, and collectively by applying the Tukey's multiple comparison test on the means of nematodes recovered. We found genotypes resistant to all tested nematodes: 7 were classified as resistant to *Heterodera glycines* (BRS Esteio, BRS Notável, BRSMG Majestoso, BRSMG Pioneiro, CNFC11954, CNFP10103, Xamego), 15 to *Meloidogyne incognita* (Aporé, BRS Embaixador, BRS Esplendor, BRS Grafite, BRS Notável, BRS Requinte, BRSMG Majestoso, BRSMG Pioneiro, CNFC 10762, CNFC 11954, CNFP 11984, IAC Alvorada, IPR Eldorado, RP 1, Rudá) and 8 to *Meloidogyne javanica* (Aporé, BRS Esteio, BRS Pontal, BRS Requinte, BRSMG Talismã, CNFC 10762, CNFP 10103, CNFP 10794) and 2 found to be resistant to *Pratylenchus brachyurus* (IPR Tangará and Light Red Kidney). The high amount of genotypes evaluated and the uniformity of experimental conditions allowed a solid base for the development of insightful discussions on the aspects involving statistical analysis of nematode data, possible sources of resistance, and the multiplication rates of important nematodes on common bean genotypes.

Keywords: Cyst-nematodes, genetic resistance, *Phaseolus vulgaris*, root-knot nematodes, root-lesion nematodes, soybean

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Contact Address: Adriane Wendland, Embrapa - Brazilian Agricultural Research Company, Agricultural Microbiology, Rua Sb 20 Qd 11 Lt 03 Portal Do Sol 1, 74884-607 Goiânia, Brazil, e-mail: adriane.wendland@embrapa.br

ID 484

Enhancing management of invasive fall armyworm under different tillage and cropping systems in Nigeria

Mobolade Akinbuluma[1], Rahman Zubair[1], Victoria Ayodele[1], Grace Sobijoh[1], Olakunle Ayodele[1], Olubisi Bamifewe[1], Oluseun Olubode[1], Olayemi Dada[1], Olajumoke Alabi[1], Miriam Karlsson[2]

[1]*University of Ibadan, Crop Protection & Environmental Biology, Nigeria*
[2]*Swedish University of Agricultural Sciences, Dept of Ecology, Sweden*

The fall armyworm (FAW; *Spodoptera frugiperda*), is a voracious agricultural pest which cause extensive damage to maize crops. Agroecology is a friendly approach that has been practised by many farmers, but the suitability of agro-ecological measures for reducing FAW densities is largely unexplored. Therefore, we hypothesised the effect of tillage and cropping systems on larval population and damage by FAW across two different landscapes in Ibadan, Nigeria. A land size (48.6 m by 32.2 m) was divided into six equal experimental units, each containing different tillage and cropping systems, namely: maize-celosia intercrop+conventional tillage (AICT), maize-celosia intercrop+minimum tillage-mulch (AIMTM), maize-cowpea intercrop+conventional tillage (CPCT), maize-cowpea intercrop+minimum tillage-mulch (CPMTM), Maize-monocrop+conventional tillage (NICT) and maize-monocrop+minimum tillage-mulch (NIMTM). The set up was replicated in two different landscapes representing areas of high tree cover (HTC) and low tree cover (LTC), with each area, having eight replicated farms. Tillage operations and mulching were carried out based on local practices and maize, cowpea and vegetable seeds were sown following standard procedures. Data on FAW larval population were collected by counting the number of FAW on 'W' point in the core plot (5 m by 5 m area), while data on foliar damage were taken using the CIMMYT pictorial guide, 1–9 (where1 = not infested; 9= heavily infested), at three, six and nine weeks after sowing (WAS). Data were analysed using analysis of variance and means were separated with Duncan's Multiple Range Test at 5 % probability level. The NICT plot had the highest number of FAW larvae in both the HTC and LTC and FAW larval population was significantly ($p \leq 0.05$) lower on minimum tillage-mulch plot than in conventional tillage plot. Foliar damage by FAW was significantly lower in HTC area than in the LTC area. It is apparent from the current study that FAW larval population and foliar damage were reduced on minimum tillage and mulching plot than conventional tillage plot as well as on maize monocrop plot than intercropped plot. The effect of high tree cover was stronger than the low tree cover in reducing fall armyworm larval population in Nigeria.

Keywords: Fall armyworm larval, high tree cover, intercropping, minimum-mulch tillage, monocropping

Molecular tools to predict resistance-breaking abilities of rice yellow mottle virus isolates

Laurence Dossou[1,3], Agnes Pinel-Galzi[2], Marie-Noelle Ndjiondjop[1], Daouda Koné[3], Eugenie Hebrard[2]

[1]*AfricaRice Center, M'bé Research Station, Côte d'Ivoire*
[2]*PHIM, Plant Health Institute, University Montpellier, IRD, INRAE, CIRAD, SupAgro, France*
[3]*WASCAL/CEA-CCBAD, Université Félix Houphouet-Boigny, Côte d'Ivoire*

Rice yellow mottle virus (RYMV, Sobemovirus, Solemoviridae) is a major biotic constraint to rice cultivation in Africa. This icosaedric (+) ssRNA virus has been described in 25 countries. It shows a high and geographically-structured genetic diversity with six major strains distributed in West or East Africa, themselves divided in several sub-lineages. This classification was based on phylogenetic analyses of the coat protein (CP) sequences and confirmed on full-length genomes. Varietal selection is considered as the most efficient and sustainable way to manage RYMV. Sources of high resistance were found mostly in accessions of the African rice species, *Oryza glaberrima*. Two recessive and one dominant resistance genes were identified. Experimental evolution on resistant accessions revealed emergence of resistance-breaking (RB) genotypes in controlled conditions. The RB ability was highly contrasted depending on the RYMV lineages and the resistance sources. We previously demonstrated that the codon 49 of the viral protein genome-linked (VPg) played a major role in the RYMV adaptation to *O. glaberrima* and that the polymorphism at this codon can be used to predict the RB ability of RYMV isolates against several resistance sources. However, sequencing of the VPg gene is required in addition to the CP sequence to determine the RYMV sublineage. Moreover, no molecular marker was available to discriminate an hypervirulent lineage able to overcome all the known resistance sources. Here, we identified a molecular signature in the P1 gene of the RYMV hypervirulent lineage. Then, we designed specific RT-PCR primers in the P1 and VPg genes. These primers were tested and validated on 50 isolates representative of the RYMV genetic diversity. They will contribute to mitigate the risks of RB emergence taking into account the RYMV lineages identified in fields and their adaptability to optimise the deployment strategy of resistant lines at the local scale.

Keywords: Molecular tools, resistance-breaking, rice, RYMV

Contact Address: Laurence Dossou, AfricaRice Center, M'bé Research Station, BP 2551, Bouaké 01, Côte d'Ivoire, e-mail: laurencedossou@yahoo.com

Comparative effects of different cabbage varieties on the bionomics of two aphid species (hemiptera: Aphididae)

Ethelyn Echep Forchibe[1], Ken Okwae Fening[1], Deric Tanka Vershiyi[1], Millicent Cobblah[2], Kwame Afreh-Nuamah[1]

[1]*University of Ghana, African Regional Postgraduate Program in Insect Science (ARPPIS), Ghana*

[2]*University of Ghana, Dept. of Animal Biology and Conservation Science, Ghana*

Lipaphis erysimi pseudobrassicae (Davis) and *Myzus persicae* (Sulzer) are important pests of brassica crops, causing significant yield losses on cabbage in Ghana. Management of these pests in the country is largely dependent on conventional insecticides, which often lead to pest resistance, environmental pollution, food safety, and health issues. To inform the development of ecologically sound and sustainable pest management strategies for these pests, their biological and population growth parameters were studied on three cabbage varieties (Oxylus, Fortune, and Leader cross). The study was conducted in a screen house under ambient conditions at $30 \pm 1°C$ and $75 \pm 5\%$ RH and 12:12 h photoperiod from September to November 2020. The parameters of the preadult developmental period, survival rates, longevity, reproduction, and life table were evaluated following the female age-specific life table. There were significant differences in the nymphal developmental time, longevity, and fecundity on the cabbage varieties for both aphid species. The highest population growth parameters, net reproductive rate (R0), intrinsic rate of increase (r), and finite rate of increase (λ) were recorded on Oxylus variety for both *L. e. pseudobrassicae* and *M. persicae*. The lowest was recorded on Leader cross variety for *L. e. pseudobrassicae* and Fortune for *M. persicae*. The results from this study suggest that Leader cross is a less suitable host for *L. e. pseudobrassicae* and Fortune for *M. persicae*, thus, should be considered as less susceptible varieties for use in primary pest management by small-scale farmers or as a component of an integrated pest management strategy for these pests on cabbage.

Keywords: Aphids, bionomics, cabbage, pest management

Contact Address: Ethelyn Echep Forchibe, University of Ghana, African Regional Postgraduate Program in Insect Science (ARPPIS), 2deer street madina un, 00233 Accra, Ghana, e-mail: echepethel@gmail.com

Effect of trap colour, cultural and sanitation measures on density of *Bactrocera zonata* in Sudan

Faiza Salah[1], Hayder Abdelgader[2], Rehab Fadwl[1]

[1]*University of Gezira, Dept. of Crop Protection, Sudan*
[2]*Agricultural Research Corporation (ARC), Crop Protection Research Center, Sudan*

Horticulture is one of the most important agricultural sub-sectors in Africa, providing income, creating jobs and enhancing food and nutrition security. Fruit flies, *Bactrocera* spp., are among the most destructive fruit/vegetable-eating agricultural pests in the world, particularly in African countries such as Sudan. The objective of this study was to investigate the effect of trap colour, cultural and sanitation Measures on density of peach fruit fly, *Bactrocera zonata* (Saunders) (Diptera: Tephritidae). Several field surveys were conducted in the Gezira State, Sudan during season 2016/2017. Three locations were selected in the study area and three sites were selected at each location. An orchard was randomly selected at each site and five directions at each orchard were determined. Methyl Eugenol trap was used to estimate the effect of colour, cultural and sanitation measures on density of the fruit flies. Data were subjected to descriptive analysis and analysis of variance procedure. The results showed that during the flowering period of mango, peach fruit fly (*Bactrocera zonata*) was highly attracted to other colours rather than the yellow colour, while, during the fruiting the insect was highly attracted to the yellow colour compared to the other colours. The density of the insects was significantly low in the well managed orchards (8.7 insects per trap per week) compared to the poor managed orchards (36.9 insects per trap per week). So the trap colour, composition of the horticultural crops, well cultural practices and good sanitation measures should be addressed when dealing with the control of peach fruit fly.

Keywords: Bactrocera, colour, methyl eugenol, peach fruit fly, sanitation

Contact Address: Faiza Salah, University of Gezira, Dept. of Crop Protection, P.O. Box20 Nishishiba, 111111 Wad Madeni, Sudan, e-mail: faizaruba2@gmail.com

The relative abundance and association between fruit flies, *Bactrocera* spp. in Sudan

Hayder Abdelgader[1], Faiza Salah[2], Rehab Fadwl[1]

[1]*Agricultural Research Corporation (ARC), Crop Protection Research Center, Sudan*
[2]*University of Gezira, Dept. of Crop Protection, Sudan*

Flies (Diptera: Tephritidae) are the most destructive insect pests of fruits and vegetables in the world. Fruit and vegetable production is one of the most important agricultural subsectors in Africa, providing income, creating employment opportunities, and enhancing food and nutritional security. Sudan has a vast and divers fruit and vegetable production zones which enable production of horticultural crops all around the year Fruits and vegetables are important components in human nutrition as they are important source for minerals and vitamins. In Sudan the production of fruits and vegetables is affected by fruit flies (*Bactrocera* spp.) that may play a major role in reducing production and limiting the exportation capabilities. The objective of the present study was to investigate the relative abundance and association between fruit flies (*Bactrocera zonata* and *Bactrocera invedens*) (Diptera: Tephritidae). Several field surveys were conducted in Wad Medani Area, Gezira State, Sudan during season 2016/2017. Three locations were selected in the study area and three sites were selected at each location. An orchard was randomly selected at each site and five directions at each orchard were determined. Methyl Eugenol trap was used to estimate the seasonal abundance of the fly among locations and sites. Data were subjected to descriptive analysis and regression analysis. The relative abundance of *Bactrocera dorsalis* (76.9 %) was higher compared to the *Bactrocera zonata* (23.1 %) at Wad Medani area, Gezira State, Sudan throughout the season 2016/17. In conclusion, the finding of this study could be utilised in sustainable pest management strategy for fruit flies (*Bactrocera* spp.) in the agro-ecological system of Gezira State, Sudan

Keywords: Abundance, *Bactrocera*, fruit fly, methyl eugenol

Assessing the tolerance of cocoa (*Theobroma cacao* L.) progenies to the black pod disease caused by *Phytophthora megakarya* bras. and griff

HERMAN EBAIARREY

University of Yaounde I, Plant Biotechnology, Cameroon

Cocoa (*Theobroma cacao* L.) belongs to the Malvaceae family and it is a diploid plant (2n = 20). It originated in the Amazon Basin (Central America) from where it spread to the other parts of the world including Africa that is today the highest producer. The greatest limitation to cocoa production is the black pod disease caused by the *Phytophthora spp*. This work aims at evaluating the tolerance of five IRAD developed cocoa hybrids of clones (PA107*SNK614, IMC67*SNK109, SCA12*SNK16, IMC67*SNK64 and T79/501*SNK64) to the black pod disease, with respect to the parental clones. Mature pods (approximately 5 months old) were harvested from the field in the early hours of the day and used to test for tolerance to the black pod disease using the Iwaro's detached pod test (DPT-SM). The means were separated using the General Linear Model (GLM) and ranked using the Student Newman-Keuls (SNK) multiple comparison test. The ANOVA showed significant difference at $p < 0.01$ on tolerance between hybrids of clones and $p < 0.001$ on tolerance between hybrids of clones and clonal groups. Forty percent of the hybrids of clones tested were more tolerant than all the clonal groups. The IMC clonal group was the most tolerant of the six clonal groups tested and it occupied third place in the overall ranking of the hybrids of clones and clonal groups tested. Although the tolerance score varied between hybrids of clones PA107*SNK614 was the most tolerant (0.79) and T75/501*SNK 64 being least tolerant (2.00), all of these hybrids of clones possesses real potential to the tolerant to the black pod disease.

Keywords: Clones, hybrids of clones, *Phytophthora megakarya*, *Theobroma cacao*, tolerance

Contact Address: Herman Ebaiarrey, University of Yaounde I, Plant Biotechnology, Nkolbisson yaounde, 00237 Yaounde, Cameroon, e-mail: hermanebai@gmail.com

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Population dynamics and damage threshold of *Pratylenchus* n. sp. and *Meloidogyne javanica* on finger millet

Beth Wangui Waweru[1], Njira Njira Pili[2], Godelieve Gheysen[1], Wim Wesemael[3], Goitom Teklu Mischina[4]

[1]*Ghent University, Molecular Biotechnology, Belgium*

[2]*Moi University, Kenya*

[3]*Flanders Research Institute for Agriculture, Fisheries and Food (ILVO), Plant Sciences Unit, Crop Protection, Belgium*

[4]*Wageningen University and Research, Plant Research, The Netherlands*

Finger millet (*Eleusine coracana* L.) is a staple crop for subsistence farmers and is primarily cultivated in arid and semiarid regions. In this study, we investigated the population dynamics, damage threshold and tolerance of the lesion nematode, *Pratylenchus* n. sp., and the root-knot nematode, *Meloidogyne javanica*, on a P-224 cultivar of finger millet. We used eleven initial population densities (Pi) of second-stage juveniles 0, 0.125, 0.25, 0.5, 1, 2, 4, 8, 16, 32 and 64 J2 (g of soil)$^{-1}$ for *M. javanica* and a mixed life stages (g of soil)$^{-1}$ for *Pratylenchus* n. sp. to inoculate finger millet seedlings. Each nematode density had eight replicates. Shoot height as growth indicator was recorded weekly, while harvestable variables fresh shoot weight, grain weight and final population densities of nematodes were determined 4.5 months after planting. The logistic growth model, Seinhorst yield loss and population dynamic models were fitted to the shoot height, plant biomass and final nematode population density. Based on the population dynamics model used parameters, maximum multiplication rates and maximum population densities for each nematode species were estimated. The maximum multiplication rates (a) were 32.39 and 17.46, whilst the maximum population densities (M) were 18.83 *Pratylenchus* (g of soil)$^{-1}$ and 19.78 J2 (g of soil)$^{-1}$ for *Pratylenchus* n. sp and *Meloidogyne javanica* respectively. The maximum height reached (C) was affected negatively with increasing Pi for both nematode genera, while the rate of growth (B) and the time to reach $0.5 \times C$ was not affected based on the logistic model. A tolerance limit (T) of 1.70, *Pratylenchus* (g of soil)$^{-1}$ and 0.65, J2 (g of soil)$^{-1}$; relative minimum grain yield (m) of 0.23 and 0.40 for *Pratylenchus* n. sp. and *Meloidogyne javanica* respectively was found. The results suggest P-224 cultivar is a good host and their presence in the field can significantly reduce yield. These findings can be used as base to develop other effective nematode management strategies for finger millet instead of rotation with P-224 cultivar.

Keywords: Host status, minimum yield, orphan crop, Seinhorst model, tolerance limit

Contact Address: Beth Wangui Waweru, Ghent University, Molecular Biotechnology, Proeftuinstraat 86, 9000 Ghent, Belgium, e-mail: bethwwr54@gmail.com

Integrated pest management is cost-effective and successfully reduced insect pests of eggplant (*Solanum melongena* var. pink ravaya) in two agroecological zones in Ghana

Therese Ngosong Nkafu, Ken Okwae Fening, Kwame Afreh-Nuamah

University of Ghana, African Regional Post Graduate Programme in Insect Science (ARPPIS), Ghana

Increased public concern over the health and environmental implication of the extensive use of synthetic pesticides to control insect pests have necessitated the need for alternative eco-friendly options. Therefore, this research was conducted to evaluate cost-effective pest management modules that could guarantee the sustainable production of *Solanum melongena* (eggplant) in the deciduous forest and coastal savannah agroecological zones of Ghana. The experiment evaluated four treatment modules [chemical intensive, less-risk, integrated control (IPM) and no spray (control)] for two cropping seasons; major and minor rainy seasons of 2020/2021. Eggplant seedlings raised in insect-proof net were transplanted onto the treatment plots and data on the abundance of insect pests and natural enemies were collected weekly, beginning two weeks after transplanting. The yield was recorded at harvest and the economics of each module was assessed for each location and season. The results showed that the abundance and dynamics of key insect pests varied across treatment modules, seasons and geographical locations. The IPM treatment had the lowest abundance of all pests (thrips, eggplant fruit and shoot borer, whiteflies, mites, aphids, leafhoppers and grasshoppers) and the highest yield and cost-benefit ratio as opposed to the control. The abundance of insect pests and eggplant yield were lower in the coastal savannah than in the deciduous forest zones for both seasons. Incorporating agroecological, seasonal and financial variability information in pest control programmes can improve the sustainability and adoption of integrated pest management programmes. This information can be used to select appropriate location-specific pest management modules for use in vegetable production in Ghana and the entire sub-region.

Keywords: Agro-ecological zone, cost-benefit ratio, integrated pest management, key insect pests

Contact Address: Therese Ngosong Nkafu, University of Ghana, African Regional Post Graduate Programme in Insect Science (ARPPIS), Legon, 00233 Accra, Ghana, e-mail: tnnkafu@st.ug.edu.gh

Diagnosis of pesticides use on off-season irrigated crops in Goulbi Maradi valley, Niger

Gabeye Djamilou[1], Martin Wiehle[2], Tankari Dan Badjo Abdourahamane[1]

[1]*Abdou Moumouni University of Niamey, Dept. of Soil Science, Niger*

[2]*University of Kassel, Tropenzentrum / Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany*

Irrigated crops represent a valid option to fight against poverty and food insecurity in sub-Saharan Africa. To optimise yields, pesticides are systematically applied, however, constituting a potential source of human and environmental pollution. This study aimed at diagnosing pesticides use on off-season irrigated crops in the Goulbi Maradi Valley, Niger, by particularly considering the age, the educational level and cropping experience of farmers. Thus, a survey was conducted in the municipalities of Djiratawa, Maradi 3, and Tibiri with 692 farmers aged between 16 to 83 years. Pearson and Chi-square correlation tests were used to correlate data. African eggplant, cabbage, moringa, and tomato, were the main irrigated crops listed. Caterpillars, aphids, mites and the weed *Cyperus rotundis* were the most important crops' opponents and all of the farmers controlled them by using pesticides. There were 60 products listed including 46 insecticides, 5 acaricides, 4 fungicides, 4 herbicides, and 1 organic. In total, 20 active ingredients were inventoried with the dominance of lambda-cyhalothrin, cypermethrin, abamectin, emamectin, profenofos and dichlorvos. Ten chemical families were identified and the most frequently used are organophosphates, pyrethroids and avermectins. With reference to the Sahelian Pesticides Committee list, 50 of these products were not authorised among which 8 are even prohibited, containing paraquat dichloride and dichlorvos. Also, 84.8 % of the farmers had not received any pesticides training and only 14 % use full outfit during treatment. As discomforts, body itching (75.7 %), cold (45.5 %), dizziness (44 %), headache (34.7 %), constipation (24.6 %), nausea (24.4 %), respiratory depression (20.4 %), diarrhea (16.8 %), and vomiting (13.3 %) were mentioned. However, most farmers took a bath (98.7 %) and drunk milk (59.7 %) as countermeasures after applications. In addition, 84.9 % of farmers conducted inappropriate phytosanitary practices including non-compliance with pre-harvest interval (49.9 %), overdosing (40.6 %), non-compliance with treatment frequency (19.4 %), lack of safety measure (14.6 %). The correlation between age, education level, and cropping experience against unsuitable application practices are all significant and negatively correlated. Indeed, urgent action and extension training offers and international efforts are required to train particularly young and uneducated farmers on the appropriate use and to probably ban and remove the stocks still available in Niger.

Keywords: Crops' opponents, discomforts, inappropriate phytosanitary practices, irrigated crops, Niger

Contact Address: Martin Wiehle, University of Kassel, Tropenzentrum / Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Steinstraße 19, 37213 Witzenhausen, Germany, e-mail: wiehle@uni-kassel.de

Soil and plant nutrition management

Online posters

Impact of integrated soil fertility management practices on smallholder farmers welfare in Ethiopia

Million Sileshi Haile[1,2], Bekele Wegi Feyisa[2], Stefan Sieber[1]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*
[2]*Haramaya University, School of Agricultural Economics and Agribusiness, Ethiopia*

This study analyses factors associated with the adoption of integrated soil fertility management (ISFMs), namely, inorganic fertiliser and SWC practices alongside the individual and combined impact on net crop value and per capita food consumption expenditure (PCFCE) using primary data collected from 781 plots in eastern Ethiopia. Multinomial endogenous switching regression is used to identify those factors associated with the adoption of these practices and to evaluate the impact of adopting them on household welfare, while taking into account both observable and unobservable biases which affect both adoption of ISFMs and outcome variables. The results reveal that ten of the explanatory variables included in the model are significantly associated with at least one of the three adoption categories: adopting inorganic fertiliser, SWC practices separately and jointly. The average treatment effects results indicate that adoption of inorganic fertiliser only, SWC practices only, and a combination of both increases net crop value by ETB 1070, 1642, and 2438, respectively, compared to their counterfactuals. Similarly, PCFCE also increased by ETB 492 for inorganic fertiliser only, ETB 407 for SWC practices adopters only, and ETB 1175 for both inorganic fertiliser and SWC practices adopters, compared to their counterfactuals. Interestingly, household welfare gains are larger when inorganic fertiliser and SWC practices are adopted in combination than if adopted separately. The policy implications resulting from this study include that designing policies or interventions that encourage the adoption of multiple agricultural technologies would help improve household income and food consumption expenditures. Most importantly, focusing on those factors found to be associated with the adoption of combination of inorganic fertiliser and SWC practices may help reap higher welfare gains from adopting ISFMs

Keywords: Adoption, Ethiopia, food consumption expenditure, inorganic fertiliser, multinomial endogenous regression, soils and water conservation

Contact Address: Million Sileshi Haile, Leibniz-Centre for Agric. Landscape Res. (ZALF), Eberswalder Str. 84, 15374 Münchenberg, Germany, e-mail: millionsileshi@gmail.com

From burning to conserving residues: The role of machinery service providers in disseminating conservation tillage

Abdullah Thaseem Muhammed Shah[1], Arshakh Thazhathu Veettil[1], Kesavanath K. Sreekumar[1], Archana Raghavan Sathyan[1], Vijayalaxmi D Khed[2], A G Adeeth Cariappa[2], Vijesh Krishna[2]

[1]*Kerala Agricultural University, College of Agriculture, Vellayani, India*
[2]*International Maize and Wheat Improvement Center (CIMMYT), India*

The green revolution has boosted cereal production in South Asia by intensifying rice-wheat systems across the Indo-Gangetic plains. However, the increased intensity has resulted in limited turn-around time between rice harvest and wheat sowing, creating a challenge for farmers to sustainably manage rice residues. Alongside mechanisation of rice harvest, this time limitation has led to burning of residues, causing air pollution and serious health externalities for human beings. Conservation tillage technologies (CTTs), such as zero-tillage and minimum tillage, could help by minimising soil disturbance and provide an economically viable use of surplus rice residue as mulch. Despite proven economic and environmental benefits, adoption of CTTs is limited in Indian rice-wheat systems. For instance, around 7 % and 34 % of farmers use CTTs like Happy Seeders and Super Seeders, respectively, in Punjab. We postulate that providing adequate access to tillage machinery through service provision can speed up the diffusion process of CTTs among smallholder farmers.

Against this background, the present study examines the adoption of resource conservation tillage technologies from a service provider perspective in the Indian state of Punjab. Key informants and service providers from 122 villages in 8 districts were surveyed in 2021. Findings suggest that the availability of CTT machines, including zero tillage drill, Happy Seeder, and Super Seeder through service providers, positively and significantly affects farmer adoption rates. Interestingly, adoption rates increase when individual service providers offer multiple machine types. Factors such as male and female labour wage rates, machine rental charges, and service provider type (e.g., cooperatives vs. private individuals) also affect the adoption rates. These results have important policy implications for increasing CTT adoption and smallholder access to mechanisation services for sustainable agriculture. Targeting service providers alongside lead farmers as "change agents" appears to be a viable option but requires the development of a feasible business model for service providers.

Keywords: Crop residue management, mechanisation, service provision

Contact Address: Vijesh Krishna, International Maize and Wheat Improvement Center (CIMMYT), Sustainable Agri-food Systems, ICRISAT Campus, 502324 Hyderabad, India, e-mail: v.krishna@cgiar.org

Deep soil carbon loss offsets rapid aboveground growth after reforestation of the Atlantic forest, Brazil

Felipe Quartucci[1], Martina Gocke[2], Manfred Denich[1], Wulf Amelung[2]

[1]*University of Bonn, Center for Development Research (ZEF), Germany*
[2]*University of Bonn, Inst. of Crop Science and Resource Conservation, Germany*

Carbon (C) sequestration following land restoration is an efficient measure of climate change mitigation. However, most studies including the international '4 per 1000' initiative focus on topsoil C only. Due to absence of the deep soil pool on land restoration assessments, studies might fail to select the most appropriate approach when it comes to C sequestration. Here, we studied the response of deep soil C to different land restoration approaches. Samples were taken from rural sites in the Atlantic Forest Biome (Brazil), using a paired site design with triplicates of different 16-to-19-year-old restoration approaches of former arable land: reforestation, natural regeneration, and agroforestry systems. Adjacent arable land and a > 25-year old secondary forest served as references. We determined aboveground and belowground C pools, including deep soil until 3 m depth. The C stock in the aboveground living biomass in the reforestation site was 85 ± 15 Mg ha^{-1}, significantly exceeding the respective aboveground C in natural regeneration (40 ± 13 Mg ha^{-1}) and agroforestry system (25 ± 5 Mg ha^{-1}), respectively. This order, however, was reversed in soil, where reforestation caused a loss of soil organic carbon (SOC) by 27 Mg ha^{-1} below 40 cm depth, whereas SOC stocks in the agroforestry system and natural regeneration site increased by 41 and 25 Mg C ha^{-1}, respectively, compared to arable land. When analysing the whole ecosystem carbon, we did not find statistical differences among the three restoration methods. We thus conclude that deep soil carbon losses can negate aboveground carbon accrual after land restoration. Not considering deep subsoil C combined with aboveground C would have led to a false ranking of the success of the land restoration practices.

Keywords: Agroforestry, carbon pools, carbon sequestration, deep soil carbon storage, land restoration, natural regeneration

Contact Address: Felipe Quartucci, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: felipe.quartucci@uni-bonn.de

Does organic manure and other soil management practices impact productivity and welfare outcomes of indigenous plant farmers in South Africa?

Abiodun Olusola Omotayo[1], Adeyemi Oladapo Aremu[2]

[1]North West University, Food Security and Safety Focus Area Res. Group, South Africa
[2]North West University, Indigenous Knowledge System Centre, South Africa

Employing a nationally representative dataset of small holder farmers in South Africa, this study investigates the impact of organic manure and other soil management practices on productivity of indigenous grain, fruits, and vegetables (IGFV), and farming households' welfare outcomes. The study adopts a multinomial endogenous switching regression (MESR) model to correct for selectivity bias stemming from both observed and unobserved heterogeneity. The average treatment effect on treated estimation results shows a significant impact of adopting organic manure in isolation and combination with other soil improvement practices. However, the highest pay-off on productivity and welfare outcomes was achieved when organic manure and other soil management practices were jointly adopted. The result indicates that joint adopters gained 40 % more on productivity compared to the 15 % and 13 % productivity increase from individual adoption of organic manure and other soil management practices respectively. Similarly, the per capita total consumption for joint adopters of organic manure and other soil management practices was thrice that of adopters of organic manure only, and 10 % higher than the adopters of the other soil management practices only. This study further finds out that rural farmer's education, wealth indicators, access to credit facilities, and access to training play a significant role in driving both individual and combinatory packages of organic manure and other soil management practices in South Africa. Overall, the study suggests that the joint adoption of organic manure and the identified soil management practices can enhance IGFV productivity and welfare outcomes of the rural smallholder farmers in South Africa.

Keywords: Food production, food sustainability, small holder farmer, soil conservation, underutilised plants

How do composting materials and duration impact compost evolution and quality in the tropics?

Felix Matheri[1], AnneKelly Kambura[2], Maina Mwangi[3], Edward Karanja[1], Noah Adamtey[4], Nancy Munyoki[1], Edwin Mwangi[1], David Bautze[4], Steven Runo[3]

[1]*International Centre of Insect Physiology and Ecology (icipe), Kenya*
[2]*Taita Taveta University, Kenya*
[3]*Kenyatta University, Agricultural Science and Technology, Kenya*
[4]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*

Compost plays a crucial role in sustainable agriculture as a rich source of organic matter, nutrients, and biota that improve soil health. Materials like *Lantana camara* and *Tithonia diversifolia* are readily available in the tropics to supplement nutrients in cattle manure during composting. There is however limited information on the succession of nutrients and microbes in compost as influenced by these materials. Moreover, prior data from the long-term farming system comparison trials in Kenya has shown significant mass and nutrient losses in compost. Compost emits GHGs which may be attributable to the nature of feedstock, duration of composting, and poor composting practices. This study sought to enumerate the contribution of composting material and duration on biological and nutrient succession in manure. A field experiment was conducted involving treatments based on grass clippings, *Lantana*, and *Tithonia* twigs with data collection every 21 days over 84 days. Other materials used in combinations were; fresh cow-dung and dry maize stalk in a ratio of 4:2:1 against the treatment material as per farmer practice. Our study showed significant losses of GHGs and nutrients during the early stages of composting with stability of these elements recorded towards the end of the composting period. However, significantly higher microbial populations were recorded at this stage but more diversity was observed at the latter stages of composting. *Lantana*-based compost had the highest microbial diversity, yet the lowest abundance among all compost treatments, implying the need for specialised microbes to break down this complex material compared to other sources. This makes it suitable for the introduction of diverse microbes to degraded soils and ecosystems but unsuitable in ecosystems requiring a rapid increase in microbial populations. Overall, the study showed that composting days had an overarching influence on nutrient evolution. We recommend mitigation measures to reduce nutrient losses at the early stages of composting.

Keywords: Biological stability, compost quality, composting duration, GHGs, green materials, nutrient losses

The effect of the dose of organic manure on the growth and agro-morphological parameters of okra (*Abelmoschus esculentus*) in the region of Fatick, Senegal

Awa Touré, Oumar Sarr, Eric Sylvain Badji

Université Cheikh Anta Diop de Dakar, Dept. Biologie Végétale, Senegal

Low soil fertility in sub-Saharan Africa is one of the constraints limiting agricultural production and justifying the effectiveness of mineral fertilisers on crop yields. However, while mineral fertilisers are generally effective during the first years of cultivation, a drop in yields is observed after five to ten years of continuous applications of exclusively mineral fertilisers. The loss of soil fertility is the main problem of Senegalese agriculture. A comparative study of the effects of organic amendments based on horse dung was carried out in order to evaluate the effect on the production and growth of of okra (*Abelmoschus esculentus*) looking at agromorphological parameters as height, diameter of the neck, and number of leaves per plant. The experiment was carried out in the Fatick region more precisely in the village Nobadane, on women managed plots with the Clemson spineless variety. The experimental device had three treatments (D0%, D50%, D100%) with three repetitions. The treatments corresponded respectively to the control without addition of organic manure (D0%), an application of 1 kg of horse dung per hill (D50%), and %), an application of 2 kg of horse dung per hill (D100%). Under the conditions of the experiment, the analysis of the results showed that the supply of organic matter had no significant effect either on the height of the plant nor on the diameter at the collar. On the other hand, D50% showed a significant effect on the number of leaves as compared to D0% and D100%. This study is important for proposing possible solutions to improve soil fertility.

Keywords: *Abelmoschus esculentus*, growth, horse dung, organic fertiliser

Contact Address: Oumar Sarr, Université Cheikh Anta Diop de Dakar, Dept. Biologie Végétale, Avenue Cheikh Anta Diop, 5005 Dakar, Senegal, e-mail: oumar9.sarr@ucad.edu.sn

Variability and critical values of nutrients in a highland banana farming system in East Africa

JoanPaula Elliseus Rutazaha[1], Jacob Kaingo[2], Peter Wilson Mtakwa[3], Godfrey Taulya[4]

[1]*International Institute of Tropical Agriculture (IITA), Tanzania*
[2]*Sokoine University of Agriculture, FoCoActive Project, Tanzania*
[3]*Sokoine University of Agriculture, Dept. of Soil and Geological Sciences, Tanzania*
[4]*International Institute of Tropical Agriculture (IITA), Uganda*

Poor soil fertility remains a major constraint in East African highland banana systems. Site-specific nutrient management practices promote attainment of sustainable yields. Critical values and their spatial distribution are an essential component for designing a sustainable nutrient management plan. This study was conducted to map the spatial distribution of nutrients and to determine the respective critical values for banana production in Rombo District, Tanzania. It involved a survey of 100 smallholder banana farms. Soil samples were collected at 0–30 cm depth along with plant samples. The samples were analysed for physicochemical properties and nutrient concentrations, respectively. Data on girth at base (Gbase) and at 1-m height from the ground (G1), number of hands per bunch and number of fingers on the bottom row of the second-last hand were collected from three selected mats per farm for allometric estimation of fresh bunch weights. Aboveground biomass (AGB) for the mother plants was also determined. Boundary line analysis was used to determine critical values. Matoke had a significantly ($P \leq 0.05$) higher Gbase, G1 and AGB than Malindi and Mshare, whereas Malindi had significantly ($P \leq 0.05$) more hands. Kriging was used to generate the nutrient distribution maps. There was no significant difference ($P \leq 0.05$) among the cultivars for fingers and bunch weight. Critical values in banana leaves were 2.39, 0.15, 1.5, 0.35 and 0.3 % for N, P, K, Ca, and Mg, respectively. Coefficient of variation was observed was in the order P>Cu>K>Zn>Mn>S. Results provide a basis for nutrient management practices and fertiliser recommendations for enhancement of yields in banana farming systems.

Keywords: Banana farming systems, critical values, kriging, soil fertility

Impact of shea waste slurry on soil physical properties

Angela Lartey-Young[1], Emmanuel Abban-Baidoo[1], George Lartey-Young [2]

[1]*University of Cape Coast, Dept. of Soil Science, Ghana*

[2]*Tianjin University of Science and Technology, Environmental Science, China*

Vitellaria paradoxa, the shea tree, grows naturally throughout the Sahelian zone in Africa. The subspecies *V. paradoxa paradoxa* can predominantly be found in the Western part of Africa. In Ghana, shea is predominantly grown in the three northern regions: Upper East, Upper West and Northern Region. The fruit from shea tree (shea fruit) is edible and contains fats. This fat when extracted from the kernel serves as an important lipid material for cosmetics, food, and the pharmaceutical industries. Shea waste slurry (SWS) is a byeproduct derived from the fat extraction process and mostly dumped. It hardens on the soil surface. This study was done to examine the physicochemical properties of SWS produced at different production sites and to investigate the effects of SWS application on soil physical properties. SWS was applied at 1 %, 3 % and 5 % (w/w) on a haplic acrisol and ultisol collected from the coastal savannah zone and semi-deciduous forest zone, respectively. The result showed that SWS had bulk densities ranging between 0.56 g cm^{-3} to 0.68 g cm^{-3}, porosity from 28 % to 40 %, water holding capacity (WHC) of 42 % to 48 %, particle density of 1.6 g cm^{-3}, void ratio of 0.51 and moisture content ranging from 25 % to 31 %. Addition of SWS increased soil porosity by 24 % and 23 %, WHC by 34 % and 25 % in the acrisol and ultisol, respectively. Soil bulk density was reduced by 11 % and 16 % respectively in the acrisol and ultisol. Correlation analysis indicated that the physicochemical properties of SWS positively correlated with physical properties of the two soil types. The possible mechanisms behind the improvements in soil physical properties by SWS application are high porosity, adsorptive nature of SWS and an efficient WHC. It is concluded that application of SWS improves the soil bulk density, enhances soil porosity and WHC.

Keywords: Acrisol, Ghana, shea, slurry, Ultisol, waste

Production of a hydroponic nutrient solution from organic residues

Sebastian Heintze[1], Marc Beckett[2], Folkard Asch[1], Jörn Germer[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*Fraunhofer Society, IGB (Inst. for Interfacial Engineering and Biotechnology), Germany*

Hydroponic plant production has great potential as food can be produced without fertile soil, and resource use is more efficient than in traditional agriculture. Nonetheless, hydroponics rely on mineral fertilisers as source for plant nutrients. A possible option to render hydroponic plant production more sustainable is bioponics, where nutrient solutions are derived from nutrient-rich organic residues. However, the nutrient compositions of organic solutions are often unbalanced and, when used in hydroponic plant production, rarely result in yields comparable to those achieved with mineral fertilisers. This study aimed to produce organic solutions rich in either N, P, or K and subsequently mix the solutions to create a nutrient-balanced hydroponic solution.

Blood meal, bone meal, and potato peel were selected as N-, P-, and K-rich residues, respectively. Each residue was mixed with water and digested anaerobically. Bone meal and potato peel for 123 days, blood meal for 54 days. The NH_4^+-rich digestate derived from blood meal was subsequently aerated for 18 days to transform NH_4^+ into NO_3^-. Samples were regularly taken from each solution and analysed for available nutrients. The three solutions were mixed based on the final NH_4^+-N, NO_3^--N, PO_4^{3-}-P, and K^+ concentrations. The resulting organic nutrient solution contained 58 mg l^{-1} NH_4^+-N, 43 mg l^{-1} NO_3^--N, 50 mg l^{-1} PO_4^{3-}-P, and 247 mg l^{-1} K^+.

The organic solution was tested against a Hoagland solution for lettuce var. Hawking in a deep water culture system for 25 days. In regular intervals the nutrient solution was replaced, plant fresh mass was measured, and samples of the initial and replaced solution were taken. At harvest, plants grown in bioponics had produced 1/3 of the fresh mass of plants grown in Hoagland solution. Poor growth of the plants grown in bioponics was attributed to an unfavourable NH_4^+:NO_3^--ratio, changes in nutrient composition, and a high microorganisms load in the organic solution.

The approach of separately digesting organic residues with high N, P, or K concentrations and subsequent mixing did not result in a nutrient solution enabling good plant growth. However, important findings regarding production and utilisation of organic nutrient solutions are presented and discussed.

Keywords: Bioponics, low-tech hydroponics, organic residue reuse, sustainability

Contact Address: Sebastian Heintze, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr. 13, 70599 Stuttgart, Germany, e-mail: sebastian.heintze@uni-hohenheim.de

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Biochar co-compost improves growth and yield of amaranth and cowpea in highly weathered sub-Saharan soils

Emmanuel Abban-Baidoo[1], Kwame Agyei Frimpong[1], Delphine Manka'abusi[2], Bernd Marschner[2]

[1]*University of Cape Coast, College of Agriculture and Natural Sciences, Department of Soil Science, Ghana*
[2]*Ruhr-Universität Bochum, Dept. of Soil Science/Soil Ecology, Germany*

Soil fertility decline is a major constraint to crop production in sub-Sahara Africa (SSA). In Ghana, the highly weathered soils are continuously cropped without any external fertiliser addition. This study was done to examine the quality of biochar co-compost produced from corn cob and rice husk biochar together with easily accessible feedstocks like domestic bio-waste, poultry litter, and rice straw, and to assess the direct and residual effects of the compost produced on soil physicochemical properties, nutrient uptake, and growth and yield parameters of amaranth and cowpea in an amaranth-cowpea cropping rotation. The study, which involved nine treatments, was conducted in pots filled with low nutrient, Haplic acrisol, Ferric acrisol and Plinthic acrisol, collected from the coastal savannah zone, semi-deciduous forest zone and guinea savannah zone of Ghana, respectively, and arranged in a randomised complete block design (RCBD). The treatments in the study included a no amendment control (Co), inorganic NPK fertiliser (IF), rice husk biochar (RHB), corn cob biochar (CCB), compost without biochar (Com), biochar co-compost containing 5 % RHB (5CoRHB), biochar co-compost containing 10 % RHB (10CoRHB), biochar co-compost containing 5 % CCB (5CoCCB) and biochar co-compost containing 10 % CCB (10CoCCB). The result showed that soil pH, electrical conductivity (EC), total nitrogen (TN), total carbon (TC), carbon to nitrogen ration (CN ratio), and available P were significantly increased in the biochar, compost, and biochar co-compost treatments compared to the un-amended control. Biochar co-compost increased soil pH by 0.8 – 1.6 units, TN by 8.4 – 46.3 %, and available P by 1278 – 5300 %, compared to the control. Soil pH in the biochar co-compost amended soils positively correlated with EC, TN, available P, and the exchangeable cations. Biochar co-compost increased biomass yields of amaranth and cowpea above 100 % in all the soil types. In both plants, N, P and K uptakes in the biochar co-composts increased with increased biochar addition (10 % biochar > 5 % biochar). We conclude that biochar co-compost application has the potential to improve soil physicochemical properties and increase crop yields by reducing nutrient losses through slower N mineralisation and higher release of P and K for plant uptake.

Keywords: Biochar, biochar co-compost, compost, growth, soil properties, yield

Contact Address: Emmanuel Abban-Baidoo, University of Cape Coast, College of Agriculture and Natural Sciences, Department of Soil Science, Cape Coast, Ghana, e-mail: eatoabban69@gmail.com

Measures to increasing availability of phosphorous in organic farming

Sawan Kushwah[1], Akanksha Singh[2]

[1]*bioRe Association, soil science, India*
[2]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*

Phosphorus is a key nutrient for food production and essential for growth and development of food crops. Though phosphorous is abundant in the soil, more than 90 % of it is not available for plants. The low availability of phosphorous for plants is due to the fact it easily binds to other elements, making it unavailable for plant uptake. Hence, phosphorous is usually added as external fertiliser in agriculture. In organic farming as synthetic P fertilisers are prohibited, natural sources of phosphorous containing material are recommended (e.g., bone meal, guano, or rock phosphate). Among these available phosphorous sources, rock phosphate (RP) is one of the most promising. However, it is a challenge to extract phosphorous from RP to make it available to plants. It is specifically a challenge to find techniques for doing so that are suitable for local context. Our study region is located in central India, where we work with approx. 3000 organic cotton farmers. Cotton is the main cash crop for farmers in our region. Here we present results from a participatory approach, where we worked with farmers to find solutions to increase phosphorous availability from RP in organic cotton production. Through farmer workshops and field visits we first identified locally available products for acidulation of RP. The products identified were tamarind, tomato, mahua vinegar, gooseberry and buttermilk then we trialed these products in farmer fields to measure their effects. Buttermilk was identified as the most promising product. Being farmer driven, adoption potential of our technique was high; however, challenges remained. We will discuss the process and challenges of such participatory research approaches and ideas to improve their sustainability.

Keywords: Buttermilk, cotton, phosphorus, rock phosphate

Contact Address: Sawan Kushwah, bioRe Association, soil science, 5th mile stone mandleshwar road kasrawad, 451228 Kasrawad,khargone, India, e-mail: sawan.mdl@gmail.com

Potential of insect frass as a bio-organic fertiliser from super worm (*Zophobas morio*) and meal worm (*Tenebrio molitor*)

Phanumat Ainta[1], Korrawat Attasopa[2], Thewin Kaeomuangmoon[1], Nuttapon Khongdee[3], Jeeranan Khomampai[1], Yupa Chromkaew[1]

[1]*Chiang Mai University, Dept. of Plant and Soil Science, Thailand*
[2]*Chiang Mai University, Dept. of Entomology and Plant Pathology, Thailand*
[3]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*

Insect frasses have literally been studied as a bio-organic fertiliser as it contains high plant nutritional values that may benefits for plant growth and yield. This study aims at comparing physical, chemical and microbiological properties of super worm (*Zophobas morio*) frass and mealworm (*Tenebrio molitor*) frass as potential bio-organic fertilisers. Insect frasses were received from the insect farm in the north of Thailand where the food source for insect is mainly from wheat bran. This study was conducted at Faculty of Agriculture, Chiang Mai University, Thailand. By using a Scanning Electron Microscope (SEM) with energy dispersive X-ray spectroscopy (EDS), the shape and size of frasses, as well as their chemical compositions by weight, were analyzed. In addition, the screening and isolation of microorganisms were analysed by serial dilution and plate count. The results demonstrated that super worm frass contains high amount of macronutrient including nitrogen (4 %), phosphorus (6.64 %), and potassium (1.47 %) while mealworm frass contains nitrogen (5.09 %), phosphorus (6.88 %), and potassium (2.29 %). Not only physico-chemical properties of frasses revealed a potential characteristic as bio-organic-fertiliser, but microorganisms screening and isolation results also found many microbial isolates that can promote plant growth (PGPs). Super worm frass can be isolated for 58 isolates including bacteria 22 isolates, fungi 1 isolate, actinomyces 13 isolates, and yeast 1 isolate and mealworm frass can be isolated for 21 isolates including bacteria 11 isolates, fungi 4 isolates, and actinomyces 6 isolates. Our findings indicated that the frasses produced by these insects, due to its nutritional content and associated microbiota, can be potentially used as a bio-organic fertiliser in organic farming.

Keywords: Insect frasses, microorganisms, plant growth promoters (PGPs)

Decomposition, greenhouse gas emissions, and nitrogen release of rice straw and its derived biochar in paddy soil under anaerobic incubation

Saowalak Somboon, Sinthara Khenkhampha, Tanabhat-Sakorn Sukitprapanon, Phrueksa Lawongsa

Khon Kaen University, Soil Science and Environment, Thailand

Organic soil amendments like rice straw improve soil fertility through the decomposition process. However, the decomposition under anaerobic conditions results in CH_4 production. Using pyrolysis to produce biochar may reduce CH_4 production and subsequently affects nutrient availability such as nitrogen in soils. This research investigated the effects of the application of rice straw (RS, $10\,t\,ha^{-1}$) and its derived biochar (BC, $3\,t\,ha^{-1}$) on decomposition, greenhouse gas emissions, and nitrogen release in a 56-day anaerobic incubation experiment of submerged paddy soil. Our results showed that the RS treatment had the highest CO_2 and CH_4 emission rates, while the BC treatment had significantly lower emission rates, similar to the control. The CO_2 emission rate of RS was higher than the BC and control from day 3, with the highest value at week 5 ($352.6\,g\,CO_2\,m^{-2}\,d^{-1}$). Meanwhile, the CO_2 emission rate in BC increased after two weeks and was highest at week 6 ($146.6\,g\,CO_2\,m^{-2}\,d^{-1}$). Conversely, the CH_4 emission rate of all treatments gradually increased after week 2. RS soil had the highest CH_4 emission rate at week 5 ($757.1\,g\,CH_4\,m^{-2}\,d^{-1}$) and BC soil had the highest CH_4 emission rate at week 4 ($1.11\,g\,CH_4\,m^{-2}\,d^{-1}$). Extractable NO_3^- content was higher in RS than in BC, while extractable NH_4^+ content was higher in BC than in RS. The highest contents of extractable NO_3^- and NH_4^+ in RS treatment were found in weeks 3 ($4.7\,mg\,kg^{-1}$) and 4 ($165.0\,mg\,kg^{-1}$), respectively. Meanwhile, the highest contents of extractable NO_3^- and NH_4^+ in BC treatment were found in weeks 4 ($2.6\,mg\,kg^{-1}$) and 5 ($285.9\,mg\,kg^{-1}$), respectively. Our findings indicated that transforming rice straw into biochar before soil application strongly reduces the decomposition and subsequently reduces CH_4 and CO_2 emissions from paddy soil. Furthermore, rice straw and biochar showed contrasting effects on NO_3^- and NH_4^+ availability that should be considered in fertilisation management.

Keywords: Methane emission, nitrogen, respiration, rice straw, rice straw-derived biochar, submerged soil

Contact Address: Saowalak Somboon, Khon Kaen University, Soil Science and Environment, 40002 Khon Kaen, Thailand, e-mail: parkayco@gmail.com

Participatory soil mapping in Benin, supported by gamma ray measurement

Chike Madueke[1], Mouinou A. Igue[2], Ludger Herrmann[1]

[1]*University of Hohenheim, Soil Chemistry and Pedology, Germany*
[2]*National Institute of Agricultural Research of Benin, Benin*

Developing land evaluation and decision support tools relies on sound data about the environment, including soils. In particular, if future options for land use at village level need to be decided, a participatory approach that is based on local terminology may be essential to bridge the language divide between farmers and researchers, and ensure effective communication. However, the level of local populations' soil knowledge is quite variable and depends to a large extent on the settlement history. Therefore, it is more secure to base a soil map not only on local knowledge, but also on additional observation or measurements. Gamma ray spectrometry has been shown to be a good and easily applicable tool for the collection of soil information using proximal sensing. In this case study in the village of Boukoussera basement region, close to Parakou, Benin, gamma ray measurements were conducted in order to verify the indigenous soil map that had initially been produced by local expert interviews. The sequence of working steps for the map establishment was as follows: 1. Indigenous soil mapping based on satellite images interpreted by local experts. 2. Soil profile description within the key units and reference gamma ray measurements. 3. Measurement of gamma ray properties in the village territory in a multiple zigzag pattern, assisted by soil augering. 4. Cluster analysis of gamma/augering data. 5. Adjustment of indigenous soil map based on the cluster results. 6. Verification of the map on the ground with local experts. 7. Final elaboration of the map based on GIS technology. The results show that the local soil types included Jaaleri, Baaduni, Taaduni and Loope. However, the gamma measurements indicated that there could be two different types of Loope, which are potentially differentiated by their inherent clay content. Site assessment and soil augering enabled the differentiation of Jaaleri into deep Jaaleri and shallow Jaaleri (around rock outcrops). Using cluster analysis, the indigenous soil map was readjusted into 7 units. These will be assessed further to produce the final soil map.

Keywords: Boukoussera, conventional soil mapping, gamma spectroscopy, indigenous soil mapping, participatory mapping, proximal sensing

Contact Address: Chike Madueke, University of Hohenheim, Soil Chemistry and Pedology, Emil-Wolft-Str. 12a, 70599 Stuttgart, Germany, e-mail: chikeonyeka.madueke@uni-hohenheim.de

Prospects and limitations of farmers' knowledge and portable sensor equipment in soil salinity assessment and monitoring: A case study from Mozambique

Jakob Herrmann[1], Júlio Lucas Muiumbo[2], Alberto Luis[3], Sebastião Famba[4], Matias Siueia Júnior[5]

[1] *Weltweit – Association for the Promotion of Local Initiatives e.V., Germany*

[2] *University Eduardo Mondlane, Fac. of Arts and Social Sciences, Mozambique*

[3] *ABIODES - Assoc. for Sustainable Development, Program for Agriculture and Food Security, Mozambique*

[4] *University Eduardo Mondlane, Fac. of Agron. and Forestry Engineering, Mozambique*

[5] *Municipal Council Maputo, Dept. for Agriculture and Extension, Mozambique*

Salinisation of agricultural soil resources is an ever-increasing problem for global sustainable food production. Smallholder farmers and extension services in affected regions of the Global South often lack the necessary infrastructure and financial resources to conduct comprehensive and timely salinity assessments. In these contexts, local knowledge systems on soil and water quality parameters prevail. In recent years, robust portable devices such as pH and electrical conductivity (EC) probes have become increasingly accessible and provide an interesting complementary tool. In order to evaluate the accuracy and validity of these alternative approaches, we conducted participatory mapping activities together with farmers of Maputo's vegetable production areas, in southern Mozambique. Farmers' salinity assessments were compared with probe-based readings in soil and water (pH, EC, activity), as well as with local standard laboratory soil analysis. Local farmers' salinity zonation compared well with soil and water measurements in a mapping exercise implemented in 2018, as examined by ANOVA and Fisher's LSD test. However, the same approach showed no alignment when conducted in a neighbouring location in 2022. This was explained by the occurrence of different constraining soil characteristics, misinterpreted by farmers as salinity. Amongst the probe-based salinity readings, activity correlated strongest with EC as determined in the laboratory (Spearman r = 0.784). Respective linear regression equations were established, considering different soil texture classes. We conclude that local farmers' evaluation may serve as a tentative proxy indicator for salinity assessment and should guide sampling approaches with the objective to reduce time and costs. However, it should be always complemented by either probe- or laboratory-based evaluations in order to more accurately characterise the salinity problem and rule out the confounding influence of possible other constraining soil parameters. For the accurate use of soil probes it is imperative to establish standardised locally adapted procedures for data collection, as well as conversion factors to standard parameters such as EC, inter alia considering the effects of soil texture.

Keywords: Land degradation, local knowledge

Contact Address: Jakob Herrmann, Weltweit – Association for the Promotion of Local Initiatives e.V., Bad Soden, Germany, e-mail: jakob@welt-weit.org

Performance of *Poaceae* cultivated in soil degraded by chromite mining in Hidrolândia, Brazil

Mariane Porto Muniz[1], Maico Roris Severino[1], Wilson Mozena Leandro[1], Richard Lord[2], João Paulo Vilela de Castro[1], Izamara Fonseca Tempesta[1], Priscyla Batista Passos[1], Ricarda Santos Batista[1]

[1]*University Federal of Goiás, School of Agronomy, Brazil*
[2]*University of Strathclyde (UoS), Civil & Environmental Engineering, United Kingdom*

Phytoremediation is a bioremediation technique that consists of the direct use of plants for the transfer or stabilisation of all potentially toxic metals in polluted soils. Bioenergy is a sustainable energy source option, however, it is often criticised for indirect changes in land use, due to lack of high quality agricultural land and competing with food production. At the same time, contaminated areas remain unused. The present study aims to provide a sustainable solution to both problems, facilitating the decontamination of land through phytoremediation with the cultivation of plants of the *Poaceae* family for energy production. The objective of this work was to evaluate the energy productivity of plants of the *Poaceae* family used in the phytoremediation of a soil degraded by chromite mining in Hidrolândia, Goiás, Brazil. The experiment was carried out in a greenhouse at the School of Agronomy at the Federal University of Goiás, Goiânia, with a dystrophic Red Latosol with a clayey texture degraded by Cr exploitation. The experimental design was in randomised blocks, with 5 treatments and 4 replications. The treatments were composed of: sugar cane, energy cane, elephant grass, capiaçu grass and spontaneous plants. The plants were cut after 6 months of cultivation for elephant and capiaçu grasses, with the sum of two cuts being performed, for sugar and energy canes the cut was made after 12 months. Productivity in terms of dry biomass and energy potential were determined. The data were subjected to analysis of variance and when differences were found, the Tukey test was applied, both at 5 % error probability. Plants from the *Poaceae* family, energy cane, sugar cane, elephant grass and capiaçu grass have good growth and development, with good biomass production in an Oxisol with high levels of Cr and Ni, being plants with potential for phytoremediation of metal-contaminated soils.

Keywords: Chromium, nickel, phytoremediation, soil

Contact Address: Mariane Porto Muniz, University Federal of Goiás, School of Agronomy; Soil Science, Av. Esperança s/n Campus Samambaia, 74.690-900 Goiânia, Brazil, e-mail: mariane.muniz@discente.ufg.br

Improvement in zinc biofortification of wheat to combat zinc malnutrition and food security issues in semi-arid regions of Pakistan

Sami Ul-Allah[1,4], Asad Azeem[2], Farukh Azeem[3], Ahmad Sher[4,1], Muhammad Ijaz[1], Abdul Sattar[4]

[1]*Bahauddin Zakariya University, Multan, College of Agriculture, Pakistan*

[2]*University of Agriculture, Faisalabad, Plant Breeding and Genetics, Pakistan*

[3]*Government College University, Faisalabad, Dept. of Bioinformatics and Biotechnology, Pakistan*

[4]*University of Layyah, College of Agriculture, Pakistan*

Zinc biofortification of wheat (*Triticum aestivum* L.) is a promising approach for addressing malnutrition and improving food security. Zinc is an essential micronutrient for human health, and its deficiency is a significant public health concern, particularly in developing countries. Wheat is a staple food for over 1 billion people worldwide, and biofortifying it with zinc could significantly improve the nutritional status of vulnerable populations. Research has shown that zinc biofortification of wheat can significantly increase the zinc concentration in the grain, leading to improved nutritional status in humans who consume wheat. Zinc biofortification can also increase crop yields, particularly in zinc-deficient soils, which can contribute to improving food security. The most logical strategy to improve Zn biofortification and agricultural productivity is to combine plant breeding with agronomic biofortification. However, its efficiency in semi-arid sub-tropical regions is not much explored. Thus, the primary purpose of this study was to assess the response of wheat genotypes to foliar application of zinc sulphate in terms of yield, grain, straw zinc content, and Zn bioavailability. Thirteen distinct wheat genotypes factorially combined with three zinc sulphate treatments (0, 0.4 %, and 0.6 %) were evaluated over the course of a two-year field experiment. Zinc sulphate and genotypes significantly ($p < 0.05$) influenced grain and biological yield, grain and straw Zn levels, and grain Zn bioavailability, and their interaction was also significant. Different genotypes exhibited a modest to strong correlation between grain zinc concentration and grain yield and grain zinc bioavailability, as determined by regression analysis. In crux, foliar Zn application boosted grain Zn biofortification and yield of wheat genotypes. Based on yield enhancement and grain zinc biofortification, the genotypes Akbar-19, Ujala, and Zincol can be recommended for increasing grain zinc content and bioavailability in semi-arid regions of Pakistan.

Keywords: Association among traits, zinc bioavailability, zinc contents

Contact Address: Sami Ul-Allah, Bahauddin Zakariya University, Multan, College of Agriculture
current address: University of Layyah, Layyah, Pakistan, e-mail: sami_llh@yahoo.com

Urochloa and biofortified maize rotation improve zinc uptake: A promising strategy to fostering human health

Madyan Vanessa Prado-Murcia, Daniel Mauricio Villegas, Mike Bastidas, José Luis Urrea-Benítez, Jacobo Arango

International Center for Tropical Agriculture (CIAT), Colombia

Biofortification of crops is a promising strategy for addressing micronutrient deficiencies in populations with limited access to diverse diets. Zinc is a critical trace element for human health, and therefore, more equitable food systems. Zinc deficiency in soil can affect plant growth and yield. The capacity of Urochloa grasses to biologically inhibit nitrification (BNI) and fix nitrogen in the soil, has been shown to improve soil health and crop productivity. In this study, we evaluated the effect of Urochloa grasses subsequently cultivated with maize on the zinc concentration in the grain. We conducted a two-year experiment in 20×20 m plots with nine Urochloa genotypes and a bare soil control, followed by four consecutive cycles of biofortified maize (SGBIOH2). Our results showed an average increase of 9.32 mg/kg of zinc in maize grain compared to the content observed in the control. The genotypes U. humidicola Uh 72 and Urochloa brizantha cv. Marandu showed the highest zinc concentrations during the planting cycles, at 37.29 mg/kg and 36.18 mg/kg, respectively, compared to the average of 25.83 mg/kg in the control treatment. Maize rotation as a subsequent crop of Urochloa grasses had a highly positive effect on zinc concentrations in the grain, enhancing its biofortifying properties. In the soil analysis, high levels of phosphorus were reported, which is inversely related to soil zinc content. Phosphorus is an essential element to produce ATP, the molecule that gives energy to the nitrifying bacteria that carry out nitrification. This may decrease the solubility and mobility of zinc, which in turn affects the nutritional quality of the plants. Brachialactone, an organic compound present in the roots of Urochloa grass, plays an important role in this interaction as it has been scientifically demonstrated that has the potential to inhibit soil microbial activity responsible for nitrification processes. By inhibiting nitrification thanks to the BNI potential of pastures and the root system of a biofortified crop, it is possible to extract and mobilise more zinc from the soil through the roots and plant tissues. Therefore, rotation with Urochloa grasses can be an effective approach to improve the nutritional quality of maize.

Keywords: Crop productivity, hidden hunger, human health, soil health

A roadmap towards the development of Zn-biofortified rice for Madagascar

Matthias Wissuwa[1], Mbolatantely Rakotondramanana[2], Cécile Grenier[3]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - PhenoRob Cluster, Germany*

[2]*FOFIFA, Rice Research Department, Madagascar*

[3]*CIRAD, UMR AGAP Institut, France*

One-third of the human population consumes insufficient quantities of zinc (Zn) to sustain a healthy life. Increasing Zn concentrations in edible parts of food crops, an approach termed Zn-biofortification, is one cost-effective option to address this problem. Especially infants in countries like Madagascar are at risk of Zn deficiency because their dominant food source, rice, contains insufficient Zn. Breeding biofortified rice varieties with increased grain Zn concentrations would offer a solution and our objective is to explore the genotypic variation present among rice gene bank accessions compared to Zn-biofortified breeding lines and local varieties. A second objective was to investigate to what extent genotype, environment and their interactions contribute to variation in grain Zn concentrations.

Multi-environment trials conducted over four seasons in Madagascar revealed that local varieties had very low grain Zn concentrations in the range of 18–20 ppm Zn, which is far below the breeding target of 30 ppm Zn. Imported Zn-biofortified breeding lines reached 25–30 ppm Zn but lacked adaptation to local conditions and therefore do not offer a short-term solution. In gene-bank accessions grain Zn concentrations up to 40 ppm were detected, especially in accessions belonging to the aus subspecies of rice native to the Indian subcontinent. Across sites and seasons variation in grain Zn was attributed to 76–78 % by genotype (G) effects with much smaller contributions by the environment (E) and genotype by environment interactions (GEI). This rather high stability of grain Zn differences across sites and years contrasted with dominant E and GEI contributions to grain yield.

This has positive implications for Zn-biofortification breeding. Selection for Zn could be centralised at very few sites in earlier generations whereas selection for grain yield and general adaptation would have to rely on multi-environment testing in later generations. High-Zn gene-bank accessions and breeding lines identified here represent suitable donors and have been crossed to locally preferred varieties in an effort to develop healthier rice varieties that can alleviate Zn malnutrition in Madagascar and other countries relying predominantly on rice in daily diets.

Keywords: Genomic prediction, grain Zn concentrations, hidden hunger, rice breeding, Zn malnutrition

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Sustainable nutrient management: Exploring transformation pathways across intervention levels

Friederike Selensky, Qirui Li, Andrea Knierim

University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany

Today's agricultural systems largely depend on finite nutrient resources N, P) that support food security but also pose a risk for mismanagement, which can lead to the eutrophication of ecosystems through leaching. In both cases, prudent management, recycling, and alternative sources of nutrients are inevitable, which calls for an urgent systems transformation. The positive influence of a wide range of agricultural practices for sustainable nutrient management has been demonstrated in many studies. However, studies on identifying efficient practices and assessing their environmental and socio-economic impacts remain often limited to one of the farm, landscape or food system intervention levels. For a systematic and comprehensive analysis of transformation pathways across levels, this study first identified publications related to nutrient management in intensive farming with a connection to transformative potential based on literature. It is followed by an analysis of barriers and benefiting actions concerning the transformation process, the key actors and factors delivering transformative changes across the farm, community, district/region, nation, and value chain levels. Finally, connections are drawn between these levels to explore potential transformation pathways through aspects such as involved actors and their interaction, rapidity of transformation, political feasibility, and social acceptance. The study's findings support the identification of common patterns and general rules or central determinants for un-/successful performance along the levels of transformation pathways in agrifood systems. Furthermore, it may provide an overview of the potential up- and out-scaling of sustainable nutrient management from different intervention levels. By drawing connections between intervention levels for selected criteria, this study contributes to the greater understanding of upscaling sustainable nutrient management and fostering its transformation. This understanding is crucial for addressing global challenges like food security and environmental drawbacks from misusing nutrients and promoting sustainable nutrient management as a viable option for addressing them.

Keywords: Nutrient management, sustainability, transformation pathway

Contact Address: Friederike Selensky, University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Stuttgart, Germany, e-mail: friederike.selensky@uni-hohenheim.de

Synergistic effects of localised application of organic and phosphorus fertiliser on rice growth and yield in P-deficient upland soils of Madagascar

Masinirina Nomenjanahary Anny Ranjakason[1], Aung Zaw Oo[2], Vivivane Raharinivo[1], Yasuhiro Tsujimoto[2]

[1]*Centre National de Recherche Appliquée au Développement Rural (FOFIFA), Dépt. de Recherche Rizicoles (DRR), Madagascar*

[2]*Japan International Research Center for Agricultural Sciences, Crop, Livestock and Environment, Japan*

Rice is a crucial crop for Madagascar's agriculture, but upland rice farmers face challenges due to limited access to fertilisers and weathered soils that bind plant-available forms of phosphate. Effective fertiliser management is necessary to increase rice production. Low-cost strategies like P micro-dosing show promise for sustainable intensification, but they are underused due to a lack of awareness and technical capacity. Uncertain soil moisture conditions due to climate change can harm early rice growth through localised P application. Combining and localised application of farmyard manure (FYM)/vermicompost (VC) and P fertiliser can mitigate the risk of chemical injury to seedlings, and increase grain yield, making it a more effective solution.

In a pot trial, both individual treatments and a combination of FYM/VC at 0.8 t ha^{-1} and P fertiliser at 5 kg and 10 kg P ha^{-1} applied in the planting hole had a positive impact on early rice growth under consistent and adequate soil moisture conditions. However, when a farmer's field trial was conducted to evaluate the same treatments on shoot biomass and grain yield, applying P locally had a negative effect on the seedlings' initial growth. This was attributed to low soil moisture levels that caused chemical damage to the rice seedlings. However, when localised FYM/VC was used, no negative effects were observed, and shoot biomass increased. When FYM/VC and P were combined, FYM/VC helped to reduce the chemical injury caused by the P fertiliser. This combination further improved early rice growth, even under field conditions with high fluctuations in soil moisture.

At harvest, the response of grain yield to localised P application depended on the P rate. A high P rate (10 kg ha^{-1}) increased grain yield by 7 %, while a P rate of 5 kg ha^{-1} did not show any difference. Grain yield increased by 24 % with localised application of FYM/VC than the control. There was no interaction between organic and P fertiliser, and their combined application additively increased grain yield by 51–82 % than the control. In conclusion, utilising local organic resources along with localised P micro-dosing promotes sustainable upland rice production in P-deficient soils of Madagascar.

Keywords: Local resource use, Madagascar, micro-dosing, phosphorus, upland rice

Contact Address: Masinirina Nomenjanahary Anny Ranjakason, Centre National de Recherche Appliquée au Développement Rural (FOFIFA), Département de Recherche Rizicoles (DRR), Lot az 89 kii E, Antananarivo, Madagascar, e-mail: annyranjakason@gmail.com

Organic waste management: The case of açaí pits as nutrient substrate to plant production in the Brazilian Amazon

Jéssica Martins de Lima, Vitor Aymoré Santos, Fernanda Miranda da Silva, Tácila Eduarda Gomes da Silva, Hanna Ferreira de Souza, Alessandra Noelly Reis Lima, Caio Vitor Conceição Costa, Nilbia Abreu Ramos

Federal Rural University of the Amazon, Brazil

Açaí (*Euterpe oleracea*) is the main source of livelihood for over 1300 small-holders in State of Pará, in the Brazilian Amazon. Açaí is a tropical fruit composed of a fine pulp membrane, and the rest is a strong pit disposed after processing, which generates significant amounts of unmanaged organic waste in the State. This research aims to study use of disposed Açaí pits as a potential low-cost, sustainable and nutritious substrate to the cultivation of vegetables in the Amazon. A pot experiment was designed using Açaí pits in three distinct conditions: in natura, fermented, and carbonized and milled, to evaluate the morphological development of onions (*Allium cepa*) in terms of root, leaf, and stalk growth, and time for the development of new leaves. The experiment was carried out in the metropolitan region of Belém in the State of Pará from March to June 2021 with controlled physical and chemical conditions. Every treatment had 5 pots with three repetitions. The treatment control pots had solely "terra preta", while other treatments had a combination of "terra preta" with respective conditions of Açaí pits. Leaves initially grew on average 18 days after the experiment set up. Estimation results show that both treatments with Açaí pits in natura and fermented did not provide positive significant influences to onion morphological development. This might be explained by the high level of fiber in Açaí pits, acting as water retainers and, consequently, having a negative influence in plants development. Conversely, the treatment with carbonized milled Açaí pits showed significant positive effects in onion leaf, root, and stalk growth. Carbonized Açaí pits might represent a positive potential for pH neutralisation in Amazonian soils, for increasing nutrient availability. This work is an initial attempt to further design appropriate management for organic waste while offering sustainable opportunities to vegetable production in the Amazon.

Keywords: Amazon, açaí, organic waste, plant nutrition, substrate

Abiotic stress

Yield and drought resistance of maize within *Gliricidia sepium* and pigeonpea intercropping systems

Anthony Kimaro[1], Johannes Michael Hafner[2]

[1]*World Agroforestry (ICRAF), Tanzania Country Programme, Tanzania*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Crop diversification through intercropping can enhance agroecosystem resilience to low and sporadic precipitations typical in semiarid areas. We tested whether intercropping maize with *Gliciridia sepium* and/or pigeonpea improves productivity and drought resistance of maize. A split-split-plot experiment was adopted to test the effects of intercropping (maize monoculture, sole pigeonpea, maize-Gliricidia, maize-pigeonpea and maize-pigeonpea-Gliricidia), fertilisers (with and without) and rainfall (ambient and drought). Drought was induced using above-canopy rainout shelters which intercepted 50 % of the ambient rainfall.

Drought reduced gravimetric soil moisture in 2019 by 12.5 % without creating artificial growing conditions under shelters. Intercropping with *G. sepium* (2.9 t ha^{-1}) and/or pigeonpea (2.5 t ha^{-1}) in 2020 did not significantly affect grain yield compared to maize monoculture (2.8 t ha^{-1}), suggesting that farmers can diversify their fields without compromising crop yields. The cropping systems by fertiliser effects on rainwater use efficiency by maize was significantly higher in 2020 and the effect was the highest when both *G. sepium* and pigeonpea were intercropped. Maize grain yield changes due to induced drought (resistance) was affected by the interactions of fertiliser and cropping systems in 2019 ($p < 0{,}05$), but no significant effects were noted in 2020. In both seasons, maize yield change was the highest (low drought resistance) in cropping system with fertiliser, suggesting that fertilisation reduced maize drought resistance. Also, nonsignificant effects on drought resistance in 2020 would reflect improved moisture conditions under the rainout shelters as precipitation in sheltered conditions (554 mm) was within the optimum range for semiarid zone. Pigeonpea yield change due to drought was not significantly affected by cropping seasons and fertiliser in both seasons. Intercropping improved resource use efficiency to increase maize yields and the appropriate selection of a drought resistant component, like pigeonpea, enhanced maize drought resistance across cropping seasons. In addition to the positive impact on drought resistance and resource efficiency, *G. sepium* provides a sustainable (regrowing) source of fuelwood. If the suggest intercropping systems are used in areas with high household dependency on fuelwood from off-farm sites, on-farm fuelwood from *G. sepium* can potentially offset this demand making the household fuelwood self-sufficient.

Keywords: Agroforestry, drought resistance, intercropping, semi-arid Tanzania

Contact Address: Anthony Kimaro, World Agroforestry (ICRAF), Tanzania Country Programme, P.O. Box 6226, Dar-es-Salaam, Tanzania, e-mail: A.Kimaro@cifor-icraf.org

Effect of salinity on nutrient uptake and growth of two genotypes of *Solanum lycopersicum* and *Cucumis sativus* under contrasting VPD levels

Hemanth Kumar Puppala, Folkard Asch, Jörn Germer

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Plants react sensitively when a certain threshold value of dissolved mineral salts in water or soil is exceeded. The resulting salt stress is one of the most severe causes limiting agricultural productivity. Therefore, research on salt tolerance and salt stress mitigation strategies is crucial.

In this study, the response of each two varieties of *Solanum lycopersicum* (cv's Saluoso, Sweeterno) and *Cucumis sativus* (cv's Addison, Proloog) to high (2.8 kPa) and low (1.7 kPa) vapour pressure deficit (VPD) at different NaCl concentrations (0, 15, 30 and 60 mM) in hydroponic solutions was investigated. Total dry weight, leaf area, nutrients (NH_4^+, NO_3, and PO_4^{3-}) uptake, evapotranspiration, plant height, leaf count, and stem diameter were recorded. Plants were partitioned into leaf, stem (upper, middle, and lower), and root to analyse the nutrient distribution (Na^+, Cl^-, and K^+). Though studies have examined the effect of salinity and humidity, our research is unique because of the analysis of the distribution of nutrients within the plant. This could provide a better understanding of the tolerant strategies of tomato salinity. At 15 and 30 mM root zone salinity, neither the total dry weight nor the leaf area of any variety was affected. At 60 mM, the dry weight and leaf area of cucumber were reduced by 88 % and 94 %, respectively, and of tomato by 55 % and 61 %, respectively. VPD did not affect the plant growth and nutrient uptake but in general biomass production, cv Saluoso performed better than cv Sweeterno and cv Proloog performed better than cv Addison with increasing NaCl concentrations. However, this difference was not significant. As with biomass production, the daily nutrient uptake was only affected at salinity levels above 60 mM root zone salinity.

With these initial results, we expect a salinity threshold between 30 and 60 mM for all plants considered. Further, we conclude that genotype selection is an easier entry point to mitigate salinity stress than VPD control for the studied species. The presentation reports on the distribution of nutrients within the plants which is currently still being analysed. Finally, we suggest methodological improvements and outline knowledge gaps and research needs.

Keywords: Nutrient uptake, cucumber, hydroponics, tomato

Contact Address: Hemanth Kumar Puppala, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 13, 70599 Stuttgart, Germany, e-mail: hemanthkumarpuppalarmp@gmail.com

Effect of salt stress on transpiration of some sweet potato genotypes

Shimul Mondal[1], Marielies Schopfhauser[1],
Md Shofiur Rahaman Ebna Habib[2], Folkard Asch[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*International Potato Center, Plant Breeding, Bangladesh*

Regulating transpiration rate under salinity is considered a salt resistant trait in some plants. Little is known about this trait in sweet potato and if plant age may affect this trait. In order to elucidate the relationship between transpiration, plant age when the stress occurs and level of salinity, four contrasting sweet potato (*Ipomoea batatas* L.) genotypes, CIP 189151.8, CIP 188002.1, CIP 106082.1 and CIP 420001 were grown hydroponically in a greenhouse at the University of Hohenheim, Germany. Salt stress (100 mM NaCl) was applied 16, 17, 18, 19, and 20 days after planting. Recording of transpiration data began after seven days of salt stress (22 days) and continued up to 28 days based on 0.5, 1.5, 2.5, and 3.0 kPa vapour pressure deficit (VPD). Dry matter, Na, K, and Cl content were analysed for each individual plant. The ranges of mean transpiration rate across VPDs varied from 0.69 to 2.68 $mmol\,m^{-2}\,s^{-1}$ under control and 0.72 to 2.85 $mmol\,m^{-2}\,s^{-1}$ under salt stress. Transpiration rate increased linearly significantly with increasing VPD without a clear salt effect in all sweet potato genotypes. Mostly, young, salt-stressed plants showed higher transpiration rates compared to the older stressed plants except CIP 420001. Although transpiration rates did not differ significantly among genotypes, sodium (Na) increased sharply in CIP 189151.8 (very high), CIP 106082.1 (very high), and CIP 420001 (slightly increased), consistent with their older age, while an opposite result was observed in CIP 188002.1. The genotype CIP 188002.1 showed similar transpiration rates with different Na accumulation. In addition, more K was found in the older plants of CIP 188002.1 with higher dry matter. The results indicate that Na uptake in sweet potato is not controlled by transpiration. We conclude that the transpiration rate of sweet potato under salinity is not indicative of salt tolerance mechanisms or Na uptake, but is based on the genotypic potential at which more K and less Na can be obtained. It is therefore suggested that further studies on Na and K uptake, distribution patterns (organ-wise), and the role of Na and K transporter channels in sweet potato plants are needed.

Keywords: Na uptake, sweet potato, salinity, transpiration, vapor pressure deficit

Salt tolerance and molecular genetic diversity analysis in chickpea (*Cicer arietinum* L.) from Ethiopia

Eden Fasika Haile[1], Ayodeji Abe[2], Kassahun Tesfaye Geleta[3], Agegnew Wasse Abegaz[3]

[1]*Czech University of Life Science, Crop Science and Agroforestry, Czech Republic*
[2]*University of Ibadan, Dept. of Crop and Horticultural Sciences, Nigeria*
[3]*Addis Ababa University, Inst. of Biotechnology, Ethiopia*

Salinity is one of the major abiotic stresses reducing chickpea growth and productivity. Genetic improvement for salt tolerance requires knowledge of genetic diversity in available germplasm. However, there is limited information on the extent of genetic variation for salt tolerance among Ethiopian chickpeas. This study was carried out to determine the extent of variability for salt tolerance and molecular genetic diversity of Ethiopian chickpeas. In a hydroponic experiment, 87 chickpea genotypes, which included 69 accessions and 18 released varieties were screened for salt tolerance. Further, the accessions were grouped into five populations namely; North Shewa, North-West Amhara, East Gojam, West Gojam and East Shewa. Plants were cultivated for 15 days in a saline solution containing 100 mM NaCl. Non-treated plants served as control. Data were collected on shoot and root growth parameters. The total dry matter percent reduction was used to classify the level of salinity tolerance of each accession. A significant phenotypic variation was marked and accessions Minjar, 207656, 41119, and 41164 were identified to be salt tolerant. A molecular genetic diversity study was conducted on 87 genotypes along with an additional 20 wild types using eight inter-simple sequence repeat markers. A high level (>95 %) of polymorphism has been obtained. East Shewa population had the highest genetic diversity (H = 0.33, I = 0.48), while North Shewa obtained the lowest diversity (H = 0.27, I = 0.41). High genetic diversity was found in salt-tolerant chickpea accessions from the North-west Amhara (H = 0.30, I = 0.44) and East Shewa populations (H = 0.30, I = 0.43). It suggests that using parental materials from those populations could be effective to improve the salt tolerance of chickpeas. Furthermore, wild types exhibited a higher genetic distance from all populations (>0.06). As a result, wild chickpeas could be exploited to improve salt tolerance in cultivated genotypes. The genetic variation for salt tolerance, as well as the molecular genetic diversity found among the chickpea accessions, will aid in the development of chickpea breeding and conservation strategies in Ethiopia.

Keywords: Chickpea, genetic diversity, hydroponics, ISSR-marker

Contact Address: Eden Fasika Haile, Czech University of Life Science, Crop Science and Agroforestry, Prague, Czech Republic, e-mail: edenfasikah@gmail.com

The effect of vapour pressure deficit on genotypic nutrient uptake and biomass production of hydroponically grown tomato

Theresa Detering, Jörn Germer, Folkard Asch

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Controlled environment farming that reduces the risks of pests, diseases and climate shocks based on hydroponics, a method of growing plants without soil, is becoming increasingly important in resource-efficient crop production. Hydroponic plant production potentially draws on a multitude of water sources including treated municipal wastewater as basis for nutrient solutions. However, reconciling the required nutrient solution quality with consistently high yields still presents a major challenge, since crop varieties may vary in their nutrient uptake dynamics as a function of water quality and environmental conditions. In order to assess the potential of wastewater in a water and nutrient management strategy, the chemical composition of the water needs to be known and the phenologically nutrient requirements of the crop under varying environments need to be understood. In a greenhouse experiment in humidity-controlled growth chambers at the University of Hohenheim, we investigated the dynamics of nutrient uptake, plant growth, and plant morphology of four tomato varieties (cv's Moneymaker, Reddery, Saluoso, and Sweeterno) grown at different vapour pressure deficits (VPD) in low concentration nutrient solution. The nitrogen concentration in the nutrient solution was kept at a level as expected in anaerobically-aerobically treated wastewater. At high VPD, cv "Saluoso" took up from the nutrient solution about 43 % more total nitrogen than "Reddery". This varietal difference increased to 64 % under low VPD. These situational responses indicate that choice of variety, adequate setting of atmospheric conditions and any combination thereof constitute important aspects for optimising nutrient uptake, plant growth, and ultimately yield for growing tomatoes hydroponically in controlled environment farming systems.

Keywords: Controlled farming, hydroponics, nutrient uptake, tomato, vapour pressure deficit, varietal difference

Contact Address: Theresa Detering, Hohenheim University, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute) - Management of Crop Water Stress, Stuttgart, Germany, e-mail: theresa.detering@uni-hohenheim.de

Understanding the genetic and physiological basis of arsenic responses and exclusion in rice (*Oryza sativa* L.)

Ambika Pandey[1,2], Lin-Bo Wu[1], Varunseelan Murugaiyan[2,3], Gabriel Schaaf[3], Jauhar Ali[2], Michael Frei[1]

[1]*Justus Liebig University Giessen, Dept. of Agronomy and Crop Physiology, Inst. for Agronomy and Plant Breeding, Germany*

[2]*International Rice Research Institute (IRRI), Rice Breeding Platform, Philippines*

[3]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*

Arsenic(As) is a toxic metalloid ubiquitously present in the environment that threatens the major rice-growing regions in the world. However, rapid industrialisation and excessive use of arsenic-rich groundwater further fuel the increased As concentration in the agricultural topsoil. Contamination of paddy soils with As cause phytotoxicity in rice which enters the food chain, posing a risk to human health. Arsenic contamination in rice is well documented, but its interaction and accumulation in rice are poorly understood. So far, no candidate genes or QTLs associated with As interaction is utilised in breeding programmes to develop low-arsenic accumulating rice varieties. Therefore, this project strives to characterise loci and genes involved in As exclusion in rice by a series of experiments that include extensive screening, genome-wide association study, development of bi-parental populations, fine mapping of genes and loci, and analysis of candidate genes and physiological mechanisms underlying As exclusion which helps in potential exploitation of alleles for breeding rice varieties with better nutritional quality. The uptake and accumulation of As in rice depend on the different As species in the soil. Plants detoxify As by conjugating and sequestering xenobiotic compounds into vacuoles using various enzymes; glutathione S-transferase enzymes are one. In one of our studies, we investigated the effects of chronic or acute exposure to arsenite [As(III)] and arsenate [As(V)] on rice plants at the vegetative growth stage using the overexpression lines of glutathione S-transferase gene (OsGSTU40). As(III) was more detrimental to plant growth than As(V) in plant growth, biomass, and lipid peroxidation in chronic and acute exposure. Overexpression of OsGSTU40 led to better plant growth even though uptake of As(V), but not As(III), into shoots was enhanced in transgenic plants. In acute As(III) stress, transgenic plants exhibited a lower level of lipid peroxidation than wild-type plants. The element composition of plants was dominated by the different As stress treatments rather than by the genotype, while the As concentration was negatively correlated with phosphorus and silicon. Overall, our findings suggest that As(III) is more toxic to plants than As(V) and that OsGSTU40 differentially affects plant reactions and tolerance to different species of arsenic.

Keywords: Arsenic toxicity, candidate genes, quantitative trait loci

Contact Address: Ambika Pandey, Justus Liebig University Giessen, Dept. of Agronomy and Crop Physiology, Inst. for Agronomy and Plant Breeding, 35390 Giessen, Germany, e-mail: ambika.pandey@agrar.uni-giessen.de

Hyperspectral estimation of pigments composition in wheat canopy layers under heat and drought field conditions

Geckem Dambo[1], Ilaria Parente[1], Alejandro Pieters[1], Francisco Pinto[2], Carlos A. Robles-Zazueta[2], Mathew Reynolds[2], Folkard Asch[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*CIMMYT Mexico, Mexico*

Wheat productivity is challenged by increases in air temperature and water deficit. Photoprotective leaf pigments play a significant role in preventing the negative impacts of these stresses. Reflectance indices have the potential to rapidly and non-destructively estimate leaf pigment composition allowing characterisation of heat and drought resilient wheat. A total of nine elite wheat genotypes developed by CIMMYT showing different resilience to drought and heat stress were grown in the field in Cd. Obregón, Mexico during the 2021/2022 growing season. The genotypes were evaluated under three different treatments, water deficit (WD), well-watered (WW) and heat stress (HS). The WD treatment was irrigated only twice during the growing season, whereas the WW treatment was irrigated throughout at regular intervals. The HS was achieved by adjusting the sowing date from December (used for WW and WD) to late February. Spectral reflectance for Anthocyanin Ratio Index (ARI), Photochemical Reflectance Index (PRI), Pigment specific simple ratio of chlorophyll a (PSSRa), Pigment specific simple ratio of chlorophyll b (PSSRb) and Pigment specific simple ratio of carotenoids (PSSRc) were used to estimate leaf pigment composition at the initiation of booting. The results showed a significant increase in the indices related to ARI in the flag leaves under HS and WD compared to WW. Lower PRI were observed in HS and WD in most leaves measured, while leaves from WW showed higher values, suggesting a higher de-epoxidation state of the xanthophyll cycle under stressful environments. PSSRc, PSSRb and PSSRa also decreased in the flag leaves in HS and WD. These results showed that reflectance indices associated to photoprotective mechanisms (ARI and PRI) were activated by HS and WD. However, HS and WD decreased reflectance indices associated to Chlorophylls and carotenoids, suggesting stress induced pigment degradation. The highest impact of HS and WD was observed in the flag compared to older leaves, which indicates that the light environment plays a modulating role on stress response of pigment composition in wheat.

Keywords: Leaf pigments, photochemical reflectance index (PRI), spectral reflectance indices (SRI), xanthophyll cycle pigments

Contact Address: Geckem Dambo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: geckem.dambo@uni-hohenheim.de

Nutritious food from salty ground: the development of an early-detection-screening-tool for salinity tolerant sweet potato varieties

Johanna Volk[1], Maria Isabel Andrade[2], Theresa Schilberth[1], Eugenio Giacopelli[1], Folkard Asch[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*International Potato Center, Flagship 2 - Adapted Productive Varieties and Quality Seed, Mozambique*

In 30 years, about half of all arable land will be affected by salinity. High-input agricultural production systems are contributing to soil salinisation through excessive fertiliser use and poor irrigation management. A typical symptom of the crop production paradigm of maximising yields while degrading the environment. An adaptive approach to food production in degraded landscapes is growing salinity tolerant varieties that yield nutritious food under challenging conditions. Field-based screening tools are a promising instrument for the detection of salinity tolerant varieties at early growth stages, especially the combination of yield-based tolerance evaluation with non-destructive growth indices. Sweet potato is considered a resilient and nutritious crop. It is a reliable staple food in many tropical countries and has high potential for the productive use of saline land due to its ability to adapt to various agro-ecological conditions. Salt stress is known to reduce yield and suppress health-promoting compounds of some varieties, while others are considered salinity tolerant. Little is known about traits suitable for effective screening of salinity tolerance across the vast number of available sweet potato varieties and to date no field-based screening tool has been developed. We suggest that such a tool is needed to explore salinity tolerant and productive candidates among diverse sweetpotato clones and detect global tolerance indices. Ultimately, it may lead to timely dissemination of invaluable information for adapted crop production. The advantage of developing a screening tool for salinity tolerance under field conditions is that yield and yield components can be determined during the trial as the agronomically relevant tolerance indicators while the resulting screening tool can recognise a large number of salinity tolerant varieties under dynamic salinity at earlier growth stages. This is possible when simultaneously to the yield components, phenology and source-sink structures are recorded. Our study tested the performance of 30 sweet potato varieties under saline drip irrigation at the CIP research station in Maputo, Mozambique. The field trial was run from transplanting to tuberous root development, laid out in a randomised block design with three replicates.

Keywords: Salinity, screening tool, sweetpotato

Contact Address: Johanna Volk, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstraße 13, 70599 Stuttgart, Germany, e-mail: johanna.volk@uni-hohenheim.de

ID 657

Effects of soil water deficit and air humidity on reflectance indices and biomass in spring wheat

Geckem Dambo, Alejandro Pieters, Folkard Asch

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Wheat productivity is challenged by increasingly frequent periods of soil water deficit. As a consequence of global warming, air humidity is also decreasing, which stimulates further water losses through evapo-transpiration. Identification and physiological characterisation of wheat germplasm resilient to both soil- and air-borne water deficit is crucial to improve yield stability under increasingly adverse growing conditions. Plants of 5 spring wheat genotypes selected from the Best Physiological Traits panel developed by CIM-MYT, were cultivated in the greenhouse at the University of Hohenheim during November-December 2022 and February- March 2023 for 6 weeks, under two different air relative humidity (average daily relative humidity 78.6 % and 36 %). Average air temperature was 31.5 OC/ 25.1 OC, (day/night). Photosynthetic photon flux density at the top of the canopy was 600 μmolm^{-2} s^{-1} kept for 14 hours a day. When 5-week-old, watering was withheld for 7 days to half of the plants, after which the flag and third leaf from top were measured for photochemical reflectance index (PRI) which is associated to de-epoxidation of the xanthophyll cycle, and SPAD as a surrogate of chlorophyll concentration. Plants were also harvested to determine dry weight and leaf area per plant. Leaf area and total plant biomass were decreased by both, soil- and air-borne water deficit. Moreover, genotypes responded differently to the stress as the genotype by stress (soil- and air-water deficit) were significant. SPAD values were decreased by air humidity in the flag leaf whereas the third leaf it was only affected by soil water deficit and the interaction between genotype and soil and/or air water deficit was not significant. The PRI of the flag leaf was not affected by either soil water deficit or air humidity, this could be due to the relatively low light intensity achieved in the greenhouse. However, genotypes did showed differences in PRI. We found no association of the spectral reflectance indices and the biomass

Contact Address: Geckem Dambo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: geckem.dambo@uni-hohenheim.de

Unlocking the resilience of yacon (*Smallanthus sonchifolius*): A systematic review

Okafor Uche Cyprian[1], Iva Viehmannova[1], Hnilicka Fransitek[2], Vitamvas Pavel[3]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Czech Republic*

[2]*Czech University of Life Sciences Prague, Fac. of Agrobiology, Food and Natural Resources, Dept. of Botany and Plant Physiology, Czech Republic*

[3]*Crop Research Institute, Division of Crop Genetics and Breeding, Plant Stress Biology and Biotechnology, Czech Republic*

Resilience to abiotic stress is essential for assuring sustainable agricultural practices and food security. Yacon (*Smallanthus sonchifolius*), a perennial tuberous crop native to the Andes, has garnered increasing attention due to its remarkable environmental adaptability. This review seeks to provide a comprehensive analysis of the physiological, morphological, and anatomical responses of yacon to abiotic stress to shed light on its resilience mechanisms. Twenty-five relevant studies were included in this review after a comprehensive search and selection process from Web of Science academic journal repositories. The findings revealed that yacon possesses a variety of adaptive mechanisms for coping with abiotic stresses such as drought, salinity, and temperature extremes. Yacon has efficient osmotic adjustment, antioxidant defence systems, and stomatal regulation, allowing it to maintain cell homeostasis under adverse conditions. Yacon exhibits enhanced root development, an increased root-to-shoot ratio, and altered leaf morphology, all of which contribute to enhanced water absorption and decreased transpiration rates. From an anatomical standpoint, yacon demonstrates structural modifications, such as increased periderm thickness, suberisation of cell walls, and the formation of aerenchyma, that enhances its resistance to abiotic stress. In addition, physiological and morphological responses are tightly linked to anatomical adaptations, allowing yacon to allocate resources efficiently and maintain growth under adverse conditions. This review provides a thorough comprehension of yacon's resilience mechanisms, highlighting its potential as a stress-tolerant crop. The findings highlight the need for additional research on the genetic and molecular aspects underlying yacon's abiotic stress tolerance, which could aid in the development of improved cultivars with increased resilience. Utilizing the adaptive characteristics of yacon may ultimately contribute to the development of resilient agricultural systems in the face of growing abiotic stress challenges.

Keywords: Abiotic-stress tolerance, adaptability, food security, resilience, *Smallanthus sonchifolius*

Contact Address: Okafor Uche Cyprian, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Kamycka 129, 165 21 Prague, Czech Republic, e-mail: okafor@ftz.czu.cz

ID 965

Induction of water stress tolerance in soybean by multifunctional micro-organisms

Enderson Ferreira[1], Adriane Wendland[1], Michel Aldrigh[2]

[1]*Embrapa - Brazilian Agricultural Research Company, Agricultural Microbiology, Brazil*
[2]*Goiás Federal University, Post-Graduation Course in Agronomy, Brazil*

Soybean is mostly cultivated in Brazil during the rainy season (October to January), when usually occurs short periods without rain, imposing water stress for the crop. Plant growth promoting rhizobacteria (PGPR) can help mitigate these stresses by inducing water deficit tolerance. The objective of this work was to evaluate the effect of PGPRs on soybean cultivated under water stress. Two water stress inducing isolates (M 163 and BRM 034008), two AIA producing isolates (Ab-V5 and BRM 063574) and two phosphate solubilising isolates (BRM 063573 and BRM 67205), as well as their combination, were evaluated, totaling 16 treatments. The experiment was carried out under greenhouse conditions in a randomised block design with four repetitions. Water stress was applied at flowering for 15 days. Plant growth (shoot dry mass - SDM, root length - RL, root surface area - RSA, root diameter - RD and root volume - RV), gas exchange (internal CO_2 concentration - Ci, transpiration - E, stomatal conductance - gs and photosynthetic rate - A) and grain yield components (pod mass - PM, pod number - PN, number of grains - NG and grain mass - GG) were determined. The treatments BRM 063574+BRM 67205+M 163, Ab-V5+BRM 67205+BRM 034008, Ab-V5, BRM 063573 and BRM 034008 increased the growth of roots and shoots of the soybean. The gas exchange parameters were benefited by BRM 063574+BRM 67205+BRM 034008, BRM 063574+BRM 063573+M 163, BRM 063574+BRM 063573+BRM 034008, Ab-V5+BRM 67205+BRM 034008, Ab-V5, and BRM 67205. On the other hand, the soybean yield components were improved by BRM 063574+BRM 67205+M 163, BRM 063574+BRM 063573+M 163, Ab-V5+BRM 67205+BRM 034008, Ab-V5, BRM 67205, and BRM 034008. Considering the response of the growth parameters, gas exchange, and grain production, the co-inoculation treatments containing the isolates BRM 063574, BRM 67205, BRM 034008 and Ab-V5 provided greater soybean tolerance to water stress. Thus, the agronomic efficiency of the isolates must be evaluated in future field tests, aiming to guarantee better productive stability of soybeans under conditions of water stress.

Keywords: Coinoculation, water stress, soybean, rhizobacteria, Brazil

Contact Address: Enderson Ferreira, Embrapa - Brazilian Agricultural Research Company, Agricultural Microbiology, Rodovia go-462 km 12, 75375-000 Santo Antônio de Goiás, Brazil, e-mail: enderson.ferreira@embrapa.br

Phenotypic plasticity and response to saline stress of seven pasture legumes

Raul Lopez[1], Bettina Eichler-Löbermann[2], Luis Rodríguez Larramendi[3]

[1]*University of Granma, Plant Biotechnology Study Center, Cuba*
[2]*University of Rostock, Agricultural and Environmental Faculty, Germany*
[3]*Universidad de Ciencias y Artes de Chiapas (UNICACH), Fac. de Ingeniería, Mexico*

The objective of this research was to analyse the phenotypic plasticity and the variation in biomass accumulation, histological and ion accumulation characters under salt stress conditions in seven grass legumes during the establishment phase under controlled glass house conditions. The effect of two salinity levels (0.02 dS.m^{-1} and 10 dS.m^{-1}) on the accumulation of area and root biomass, histology, and the accumulation of nitrogen, sodium, and potassium were evaluated. Phenotypic plasticity in response to salt stress was calculated in the studied legumes. The characters related to biomass accumulation were significantly affected by salt stress in all legumes studied. As for the histological indicators evaluated, the behaviour showed that salt stress caused a decrease in the width and length of the stomata and an increase in stomatal frequency and histological thickness. The study of the effect of salt stress on the accumulation of ions shows a significant reduction in the content of nitrogen and potassium and a significant increase in the content of sodium in all the species studied. The species *Sesbania rostrata*, *Centrosema pubescens*, *Macroptilium lathyroides*, *Clitoria ternatea*, and *Canavalia ensiformis* showed mean values above 0.40 of phenotypic plasticity for characters related to biomass accumulation. *Macroptilium atropurpureum* and *Leucaena leucocephala*, although they present plasticity, were the species that showed the lowest values. The histological characters evaluated in the legumes studied showed very low values of phenotypic plasticity, although with significant differences between them. Phenotypic plasticity in grass legumes as an indicator of tolerance to salinity. Salinity has a negative effect on the morphological, histological and ion accumulation characters studied in grass legumes. *S. rostrata*, *L. leucocephala*, *C. ternatea*, *C. pubescens*, and *C. ensiformis* showed the highest phenotypic plasticity index in the studied characters against salt stress. The dry matter characters of the aerial part and the root and the accumulation of nitrogen turned out to be the ones with the highest phenotypic plasticity Index in the presence of saline stress.

Keywords: Biomass accumulation, legumes, phenotypic plasticity, salinity

Contact Address: Bettina Eichler-Löbermann, University of Rostock, Agricultural and Environmental Faculty, Justus-von-Liebig-Weg 6, 18059 Rostock, Germany, e-mail: bettina.eichler@uni-rostock.de

Could pigmented rice be an alternative variety for increased nutritional security and mitigation of salinity stress?

Aung Zaw Oo[1], Sun Minyu[2], Hidetoshi Asai[1], Ikeura Hiroshi[1], Homma Koki[2]

[1]*Japan International Research Center for Agricultural Sciences, Crop, Livestock and Environment, Japan*

[2]*Tohoku University, Graduate School of Agricultural Science, Japan*

Black rice, known for its antioxidant properties, is grown by resource-poor farmers in unfavourable conditions. Salinity stress is a significant problem for rice production, but black rice's antioxidant properties improve plant tolerance to stress. The hypothesis is that black rice's high antioxidant levels will help it adapt better to salinity stress, maintain high yield, and improve grain nutrient parameters. In a pot experiment, black rice (Asamurasaki) had a small yield reduction (12 %) under moderate salt stress (6 dS m^{-1}) compared to white rice (Hitomebore) (20 %). Under high salt stress (12 dS m^{-1}), black rice and white rice had a larger yield reduction of 58 % and 64 %, respectively. While high grain yield was maintained under salt stress, black rice showed significant increases in grain flavonoid and phenolic content, with higher levels of these antioxidants under higher salt stress. Black rice produced under salt stress had a significantly reduced lightness L* value, which improved visual grain quality, particularly due to the high levels of antioxidants in the grain under salt stress. Two-year field trials using simulated frequent saltwater intrusion showed that the rate of yield reduction in black and white rice was similar, ranging from 8.5 % to 8.7 % in year 1 (3 dS m^{-1}) and increased to 25.9 % and 26.8 % in year 2 ($\geq$5 dS m^{-1}) due to increased salt stress. Salt stress substantially increased grain flavonoid and crude protein content in black rice, and the effect was more pronounced in year 2. In contrast, no difference in grain antioxidant content was observed between the control and salt stress in white rice. Black rice exhibits moderate salt stress tolerance, causing only a slight yield reduction and increased phenolic and flavonoid compounds. Severe salt stress leads to yield losses but also increases antioxidant levels. Therefore, black rice is a suitable option for cultivation in areas with moderate salt stress, sustaining production while improving the nutritional value of grains for human consumption.

Contact Address: Aung Zaw Oo, Japan International Research Center for Agricultural Sciences, Crop, Livestock and Environment, 1-1 ohwashi, 3058686 Tsukuba, Japan, e-mail: aungzawoo@affrc.go.jp

The role of ionic and osmotic stress on the response of rice to salinity stress

Kristian Johnson, Folkard Asch

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

More than half of the world's population rely on rice (*Oryza sativa* L.) as an essential daily staple. Despite growing demand, agricultural land in key rice producing areas is being degraded due to a combination of urbanization, soil salinization, and erosion. Soil salinization is typically the result of poor agricultural practice in arid areas. However, increasingly it is also a problem in some of the world's wettest regions due to sea level rise. This threatens rice production, as rice is a highly salt-susceptible crop. Salinity stress relates to two processes, an initial osmotic shock that leads to reduced water uptake by the roots, followed by a toxic accumulation of ions within the plant. The effect of the separate phases on rice plant growth remains unexplored and may even differ significantly between rice varieties. As a result, the determination of the respective contributions of ionic and osmotic phases to the overall effect of salinity could provide greater insight into mechanisms underlying salinity tolerance. Our objective was to differentiate and measure the osmotic and ionic components of salinity using polyethylene glycol-6000 (PEG) and NaCl treatments of different severities in a greenhouse experiment conducted at the University of Hohenheim. We used three rice varieties (IR4630, IR31785, IR64), each with strongly contrasting salt tolerance mechanisms, and subjected them during their vegetative stage to different levels of salinity and osmotic stress. Biomass, leaf area, SPAD, PRI, ion content (Na^+, Cl^-, K^+) on a plant and organ level, leaf relative water content, leaf turgor, photosynthesis, and transpiration at a leaf and canopy level were measured after one and then two weeks of salinity and osmotic stress. The comparison of osmotic to salinity treatments, which were osmotically equivalent, will indicate the extent of the contribution of osmotic and ionic components to salinity stress and allow us to identify the aspects of plant growth on which either one has the greatest influence. The potential effect of variety will also be shown.

Keywords: Ionic vs. osmotic stress, rice, salinity stress

Contact Address: Kristian Johnson, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr.13, 70593 Stuttgart, Germany, e-mail: k.johnson@uni-hohenheim.de

Landscape and land use

Optimisation strategies, synergies and trade-offs between sustainability, productivity and profit in farming systems

Online posters

Co-designing and scaling sustainable intensification of mixed farming systems in Laos

Soytavanh Mienmany[1], Mary Atieno[2], Riina Jalonen[1], Horst Weyerhaeuser[3], Michael Peters[4], Jonathan Newby[1], Simone Vongkhamho[5]

[1]*Independent Researcher, Laos*

[2]*The Alliance of Bioversity International and CIAT, Laos*

[3]*Independent Researcher, Thailand*

[4]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Kenya*

[5]*Ministry of Agriculture and Forestry, National Agriculture and Forestry Research Inst., Laos*

For over a decade, rural Lao households have been undergoing a transformation from subsistence-oriented production systems to agricultural commercialisation, facilitated by a series of Lao government policies opening the economy to international markets coupled with improved connectivity. The extent and depth of this process is accelerating, particularly in upland (non-paddy) farming systems that were formerly part of a swidden landscape. Sustainable intensification of these mixed crop-tree-livestock systems (mixed farming systems, MFS) is critical for competitiveness in global markets, long-term productivity and efficiency of resource use, without undermining resilience and ecosystem services for rural households. Cassava and cattle are amongst the most recent in a series of commodity booms in which increased market demand and farm-gate prices has seen farmers engaged in a process of specialisation and mono-cultures to capture market opportunities.

This research explores MFS's policy and market context, its impacts on farming practices and the opportunities and entry points for co-designing sustainable intensification, focusing on cattle in Northern and cassava in Southern Laos. We conducted interviews with local government staff, farmers and other stakeholders in three provinces in Laos with diverse agricultural commercialisation and markets. Initial results reveal the cassava boom has been driven by the high price of cassava root and chips, access to the local and global markets and the establishment of starch factories in Laos and neighbouring countries; the cattle boom has been driven by government policy, high demand for cattle export to China and Vietnam and the decline of maize production and price. Farmers practise MFS based on their available inputs and labour with insufficient technical and innovation skills, although some larger landowners have adopted good practices such as crop rotation and silvopasture. The cassava and cattle booms contribute to converting forest areas

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Contact Address: Soytavanh Mienmany, Independent Researcher, 303 Residence of MOES, Pakhao Village, Xaythany District, Vientiane Capital, Laos, e-mail: soytavanh@gmail.com

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into agricultural commercial landscapes, and affect the availability of ecosystem services such as access to land for grazing, soil fertility, erosion control and watershed protection. To reduce negative impacts on the environment and agroecosystems, improving farmers' technical and innovation capacities, co-design and supportive policies and regulations are needed to optimise resources. Agro-silvo-pastoral systems are crucial for this pathway.

Keywords: Cassava, cattle, co-designing, maize, mixed crop-tree-livestock systems, Northern and Southern Laos

Climate-driven crop suitability effects on conflict in sub-Saharan Africa

Lisa Murken[1], Chiara Sophia Weituschat[1], Abel Chemura[1], Christoph Gornott[2]

[1]*Potsdam Institute for Climate Impact Research (PIK), Germany*
[2]*University of Kassel & Potsdam Institute for Climate Impact Research (PIK), Fac. of Organic Agricultural Sciences, Germany*

Climate change fundamentally affects agricultural systems and agricultural households. This can have implications that reach far beyond agriculture itself. An active field of study is the potential effect of weather and climate on conflict dynamics, with several channels explored in the literature that may explain why weather and climate events affect conflict propensity and intensity. In particular, climate-induced resource scarcity could ignite conflicts. In this study, we analyse a specific impact channel that may explain weather influence on conflict in areas with high agricultural dependency: changes in crop suitability. Crop suitability can be modeled using machine learning approaches and as a function of climate and spatial indicators. We use crop suitability models for the entire African continent to analyse influences of crop suitability changes on conflict incidence and intensity from 1997–2023, drawing on the ACLED database for conflict data. Focusing on the main crops produced in Africa, we distinguish between food crops and cash crops. The main hypothesis is that changes in crop suitability require replanting, reorganisation of plots and potentially abandonment of previously fertile areas. Such changes could influence demand in land, land transfers, and ultimately land conflict. Presumably, areas that are not directly affected by crop suitability changes but lie in the vicinity could be particularly affected through spatial spillovers, where pressure increases on land from areas that are affected by changes in suitability. Areas of particular interest include areas "at the fringe", where crop farming and livestock production meet. Based on the empirically derived relationship between crop suitability changes and conflict occurrence, we conduct a back-of-the-envelope calculation to estimate potential future hotspots of conflict occurrence based on projected crop suitability, taking into account different climate scenarios. The results of this study will shed new light on the weather, climate, agriculture and conflict nexus, which can inform policies for sustainable land management with the aim of conflict prevention.

Keywords: Agricultural potential, climate change, conflicts, crop suitability

Contact Address: Lisa Murken, Potsdam Institute for Climate Impact Research (PIK), Telegraphenberg A31, 14473 Potsdam, Germany, e-mail: murken@pik-potsdam.de

Developing macaúba value webs: A novel oil crop, multipurpose palm for agricultural diversification in Brazil

Ricardo Vargas-Carpintero[1], Thomas Hilger[2], Sérgio Motoike[3], Leonardo Pimentel[3], Carlos Colombo[4], Roseli Ferrari[5], Peter Eisner[6], Sérgio Toledo e Silva[6], Stephanie Mittermaier[6], Iris Lewandowski[1]

[1]*University of Hohenheim, Dept. Biobased Resources in the Bioeconomy, Institute of Crop Sciences, Germany*

[2]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics, Acrocomia Hub, Germany*

[3]*Federal University of Viçosa, Dept. of Agronomy, Brazil*

[4]*Agronomic Institute of Campinas, Genetic Resources Center, Brazil*

[5]*Food Technology Institute (ITAL), Brazil*

[6]*Fraunhofer Institute for Process Engineering and Packaging (IVV), Germany*

The development of novel crops is a key strategy towards the diversification of agriculture and raw materials for the transition to a sustainable biobased economy. In this context, biodiversity and ethnobotanical knowledge offer a pool of genetic resources. The macaúba palm (*Acrocomia aculeata*) is an example. This plant, native to the neotropics, widely adapted to adverse ecological conditions and traditionally used by local, rural communities, can deliver multiple functions simultaneously: oils from the fruits in high quantity and quality (2,5 to 5 tons of oils ha^{-1}), residual fruit fractions for various applications, recovery of degraded landscapes and soils, carbon sequestration and biodiversity habitat. Scientific progress has allowed its initial cultivation in Brazil, facilitating the transition to a semi-domesticated phase. A systems approach is fundamental at this early stage of macaúba value web's development to achieve sustainability and successful crop introduction, integrating cultivation, processing, and products. Moreover, the involvement of different stakeholders and the consideration of contextual factors are elemental actions for shaping these systems sustainably. For instance, plant breeding needs to be aligned with industrial applications, cropping systems tailored to biophysical parameters and farmers' conditions, and biomass supply with processing demand. In the "AcroAlliance" project, we incorporate these principles and conditions in the development of macaúba value webs. By combining inter- and transdisciplinary researchers' expertise on genetics, agronomy, processing technology for fruit biorefining into high-added value products and sustainability assessment, the project aims to propose an integrated macaúba value web concept. For this, our targets are: i) advancing planting material; ii) modelling cropping systems (e.g. agroforestry) and identifying

Contact Address: Ricardo Vargas-Carpintero, University of Hohenheim, Dept. Biobased Resources in the Bioeconomy, Institute of Crop Sciences, Fruwirthstr. 21, 70599 Stuttgart, Germany, e-mail: ricardo.vargas@uni-hohenheim.de

best agricultural practices; iii) improving harvest and post-harvest processes; iv) developing a biorefinery concept for the production of oils, proteins and fibres; v) testing industrial applications; vi) analysing the value web, identifying implementation strategies and setting a roadmap. Farmers and companies fostering the cultivation of macaúba and industry actors are involved in order to ensure knowledge transfer and a reflective research process. This project contributes to the advancement of a novel crop from plant biodiversity and thus, the diversification of agricultural activities and products.

Keywords: *Acrocomia aculeata*, agricultural value chains, agroforestry, biobased value web, biodiversity, bioeconomy, biorefinery, Brazil, diversification, Macaw palm, macaúba, novel crops, oil crops, palms, sustainability

Resource allocation trade-offs in smallholder cropping systems using multi-objective optimisation

Christine Arwata Alum

Biodiversity Solutions Ltd, Uganda

Decision-making in typical smallholder farms is usually comprised of multiple objectives that need to be put under consideration. These objectives are sometimes in conflict with each other. Farmers therefore aim to efficiently utilise farm resources to attain satisfaction from all its objectives. However, the problem lies in allocating the limited resources to farm operations. Admittedly, resource use varies in different cropping systems. Due to the existence of several objectives, Multiple Criteria Decision Making models are used to solve trade-off problems consisting of multiple objectives. This study applies a compromise programming model to analyse the conflicts between the economic, social and nutritional objectives of a typical resource-poor farm in eastern Uganda and develop the optimal cropping plan for the farm's cropping systems. Compromise solutions were generated following four analytical procedures, that is, individual objective optimisation to identify the ideal solution, constrained optimisation to generate a set of efficient solutions, deviations between the objective values and their ideal points were obtained and a distance measure was introduced to identify the best compromise solution. Results demonstrate how relationships between farm components and cropping systems influence farm labour demands, income and nutrition. Different trade-offs occur between the farm's objectives in the cropping systems modelled. The results show that farm income reduces as farm labour in terms of hours reduces. Additionally cropping plans that promoted better nutrition included the cultivation of crop mixtures, that is, maize and beans intercrop. On the other hand, a higher income was realised when the model allocated a larger acreage to coffee production. Furthermore, findings reveal that competition exists between allocating the farm's labour resources to produce different crops. The efficient solutions generated by the procedure provide an understanding of the trade-offs existing between conflicting farm objectives. Therefore, the model helps to assess the potential for the adjustment of other crops in achievement of objectives. Policy suggestions could focus on sustainable intensification strategies such as polycultures, to utilise available farm resources.

Keywords: Compromise solution, constrained optimisation, decision-making, efficient solutions, multiple criteria decision making, polyculture, Uganda

Contact Address: Christine Arwata Alum, Biodiversity Solutions Ltd, Kampala, Uganda, e-mail: christinealum@gmail.com

Emerging pathways in changing rice-based production systems in Luzon, Philippines

Richelyn Rose Clavero[1], Manuel José C. Regalado[2], Mathias Becker[1], Shyam Pariyar[1]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*

[2]*Philippine Rice Research Inst., Rice Engineering & Mechanization Div., Philippines*

External pressures and internal drivers are shaping processes of change in rice-based production systems. We studied to what extent and in which ways rice-based production systems are impacted by the recently implemented Rice Trade Liberalisation Law (RTLL) in the Philippines, a policy aimed at lowering rice prices for urban consumers. Through a diachronic analysis (comparing the years 2018 and 2022), we assessed changes in production practices and performance attributes in four main rice producing provinces in Luzon, representing either rainfed (Pangasinan and Bulacan) or irrigated (Aurora and Nueva Ecija) systems, and in both the dry (DS) and the wet seasons (WS). Structured surveys administered to 600 farmers complemented focus group discussions.

In 2022, the Philippines has increased the amount of cheap imported rice by 48 % (2,975,310 metric tons in 2021 vs. 2,006,350 metric tons in 2018), thereby halving the price of paddy rice for farmers and increasing uncertainties on the outcome of farmers' investments. Three years after implementing the RTLL, we observed major changes in land use and in agronomic practices. Across sites, the paddy rice area decreased by 2 – 20 %, with largest changes in Nueva Ecija in both seasons. Crop establishment of dry season rice shifted from transplanting to direct seeding in 81 % of all observed cases in Bulacan, and in 13–20 % in Nueva Ecija and Pangasinan. In Aurora and Pangasinan, 69 and 52 % of farmers respectively, also shifted to direct seeding their wet-season rice. Adoption of these labor-saving practices entailed a significant increase in the use of herbicides. Due to recently massively increased costs, N fertiliser application rates decreased in the DS in Aurora and in Nueva Ecija as well as in the WS in Bulacan and Pangasinan, significantly and negatively affecting grain yields at these sites and seasons. Another emerging trend associated with the RTLL concerns a shift from DS rice to high-value upland crops, especially in rainfed environments and on light-textured soils.

The combined effects of these RTLL-related changes point towards a future trend of uncertainties in rice supply with decreasing domestic production and food sovereignty and an increased import dependency for rice in the Philippines.

Keywords: Cropping system shift, diachronic analysis, food security, *Oryza sativa*, rice tariffication

ID 856

Treated wastewater usage for agriculture in water stress areas: A case study in Sialkot, Pakistan

Jawwad Shafiq

PICIIP, Local Government & Community Development Department, Environment Safeguards, Pakistan

Punjab, the most populous province in Pakistan, relies heavily on agriculture, which produces over 70 % of the country's food crops. However, the region is facing a severe water crisis that threatens the sustainability of its agricultural sector. This crisis has been exacerbated by urbanisation, climate change, and increased competition for water from other sectors, including industry and domestic use. The city of Sialkot, located in central Punjab, is home to around 270 leather tanneries and other industries that are the largest users of water and depend entirely on groundwater sources. Due to climate change and over-exploitation of water resources, farmers face serious challenges in accessing safe water. Effluents from tanneries, industries, and municipalities are discharged directly into freshwater streams, forcing farmers to use wastewater for irrigation, which poses a serious threat to human health and reduces land fertility due to salinisation after a few times. To address this issue, Sialkot's local government has planned to use treated wastewater for irrigation to meet the agricultural sector's water needs. The Water-Energy-Food Nexus approach was used to evaluate the feasibility of collecting and reusing wastewater for irrigation after applying suitable treatments, and GIS-based tools were used to coordinate water supply and demand. Five treatment technologies for domestic wastewater were compared, where the levelized cost of water method was used to determine the best low-cost system and the waste stabilisation ponds (WSP) method was found to be the most suitable for treating captured wastewater. The adoption of this irrigation scheme would result in a noticeable improvement of local water resources, ensure the long-term sustainability of the agricultural sector and improve the livelihoods of millions of farmers who depend on it. It would also reduce water extractions by around 30 % and total energy requirements for groundwater pumping by around 15 %, contributing to a more sustainable and resilient food system in Punjab.

Keywords: Food production, irrigation, low-cost system, sustainability, wastewater use

Promotion of mechanisation for smallholder farmers: Insights and learnings from Zambia

Carolin Rosenberg

University of Duisburg-Essen, Institute for Development and Peace (INEF), Germany

The agricultural sector in Zambia has so far been characterised by low mechanisation. Most farmers still cultivate and maintain their land by hand, with negative consequences for productivity. Not only is less arable land cultivated than is available, but farmers are also unable to make optimal use of the time slots favourable for planting and weed control. A major reason for the often unproductive farming methods is the lack of access to financing for agricultural equipment.

In 2017 KfW Development Bank supported the establishment of Agricultural Leasing Company Zambia Limited (AgLeaseCo), which aims to promote agricultural modernisation in Zambia through an innovative leasing scheme. The target group of the private Zambian company are primarily wealthier smallholder farmers who cultivate between 5 and 20 hectares of land. By providing financing in the form of leasing, these farmers are supported in modernizing their farming methods through the acquisition of equipment, such as tractors, cultivation implements, or planters. By lending their leased machinery to surrounding farmers for a rental fee, also smallholder farmers who are not (yet) able to obtain agricultural equipment themselves benefit.

A team from INEF, University of Duisburg-Essen, analysed this good practice example of promoting agricultural modernisation in Zambia through focus group discussions with benefitting farmers and interviews with key stakeholders involved in the leasing process (e.g. AgLeaseCo staff, equipment suppliers, traditional leaders). The INEF-team looked into AgLeaseCo's business model, farmers' investment preferences, the lease's impact on agricultural productivity and livelihoods, as well as challenges and problems throughout the leasing process. Especially, the impact on poorer smallholders, who achieve (partial) mechanisation through hiring leased machinery, was looked into. The research thereby examined the question of how the introduction of modern means of agricultural production can affect both the area cultivated as well as the yields and incomes of smallholder farmers, and can thus ultimately contribute to poverty reduction and food security in rural areas.

The contribution aims to present the case studies' innovative idea and lessons learned derived from the research results, and to explore pathways to transfer this good practice for promoting agricultural modernisation to other contexts.

Contact Address: Carolin Rosenberg, University of Duisburg-Essen, Institute for Development and Peace (INEF), Lotharstraße 53, 47057 Duisburg, Germany, e-mail: carolin.rosenberg@uni-due.de

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A tool for analysing sustainability of smallholder farms: Farm input subsidy policy use case

Powell Mponela[1], Quang Bao Le[2], Grace Villamor[3], Lulseged Tamene[4], Christian Borgemeister[3]

[1]*The Alliance of Bioversity International and CIAT, Ghana*
[2]*International Center for Agricultural Research in the Dry Areas (ICARDA), Egypt*
[3]*University of Bonn, Center for Development Research (ZEF), Germany*
[4]*International Center for Tropical Agriculture (CIAT), Agroecosystems and Sustainable Landscapes Research Area, Ethiopia*

The research and development needed to achieve sustainability of African smallholder agricultural and natural systems has led to a wide array of theoretical frameworks for conceptualising socioecological processes and functions. However, there are few analytical tools for spatio-temporal empirical approaches to implement use cases. This is a prerequisite to understand the performance of smallholder farms in the real world. This study builds a multi-agent system (MAS) to operationalise the Sustainable Agricultural Intensification (SAI) theoretical framework (MASSAI). This is an essential tool for the spatio-temporal simulation of farm productivity to evaluate sustainability trends into the future at fine scale of a managed plot. MASSAI evaluates dynamic nutrient transfer using smallholder nutrient monitoring functions which have been calibrated with parameters from Malawi and the region. It integrates two modules: the Environmental (EM) and Behavioural (BM) ones. The EM assess dynamic natural nutrient inputs (sedimentation and atmospheric deposition) and outputs (leaching, erosion and gaseous loses) as a product of bioclimatic factors and land use activities. An integrated BM assess the impact of farmer decisions which influence farm-level inputs (fertiliser, manure, biological N fixation) and outputs (crop yields and associated grain). A use case of input subsidies, common in Africa, markedly influence fertiliser access and the impact of different policy scenarios on decision-making, crop productivity, nutrient balance and economic benefits are simulated. This is of use for empirical analysis smallholder's sustainability trajectories given the pro-poor development policy support. For 15 years the government of Malawi has championed input subsidy as a pro-poor strategy to ensure food security, poverty reduction and improved nutrition but its impact on human behaviour and soil nutrient balance as indicators of sustainability has not been evaluated. After the 15 years of fertiliser subsidy program, farmers have internalised it in their expenditure plan: some source increasing amounts from the market while those that rely on limited fertiliser acquired through subsidy proactively reduce the nutrient gap by increasing manuring. Subsidy might not significantly shift the nutrient and productivity trajectories for the next 20 simulated years, increased subsidy could relatively accelerate nitrogen gain but lead to phosphorus losses thereby jeorpardising farm sustainability.

Keywords: Farm input subsidy, multi agent system, nutrient balance

Potential of agrivoltaic system for lettuce plantation in a non-irrigated small scale areas: Case study in northern Thailand

Suwimon Wicharuck[1], Nuttapon Khongdee[2], Chatchawan Chaichana[1]

[1]*Chiang Mai University, Energy Technology for Environment Research Center, Thailand*
[2]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*

Solar energy, in terms of solar PV, has gained more interest these days as a substitute for fossil fuels in generating electricity. A solar farm requires a significant quantity of land for PV installation, and it is expected to compete for land with agriculture. The idea of growing crops below the PV has recently become popular. Therefore, this study aims to investigate the possibility of crop production under solar PV on lettuce growth and yields. The study area was located in Hang Dong district, Chiang Mai Province, Thailand. Two growing systems were compared: lettuce plantation i) in a greenhouse as a control (GH) and ii) below the solar PV (SL). Lettuce varieties (*Lactuca sativa*) of 'Butter Head' (BH) and 'Green Oak' (GO) were selected for comparative measurement. The lettuce was planted in both GH and SL systems. Light intensities were recorded as Photosynthetically Photon Flux Density (PPFD, μmol/m^2/s) every 30 mins and the values were then converted to daily light integral (DLI, mol/m^2/d). SPAD values (using the Chlorophyll Meter SPAD-502), growth (height and width) and fresh yields were measured every 7 days. The results showed that PPFD values in GH (538 μmol/m^2/s) were higher than in SL (404 μmol/m^2/s), with a ratio of 28 %. At maturity, the highest values of SPAD were observed under BH_GH of 36.2 in comparison to the others during the measurement date. GO_SL had the highest values of plant height (14.8 cm) and width (21.0 cm) while the lowest values were observed in BH_SL (height = 10.4 cm and width = 11.9 cm). Fresh yield showed the highest and lowest values in GO_SL and BH_SL, with average values of 41.8 g/plant and 25.4 g/plant, respectively. In conclusion, sunlight availability under the PV was adequate for growing lettuce but further investigation is needed for the other crops.

Keywords: Agrivoltaic system, lettuce plantation, solar energy

Contact Address: Nuttapon Khongdee, Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Huay Kaew Road, 50200 Chiang Mai, Thailand, e-mail: nuttapon.k@cmu.ac.th

Agricultural production practices, challenges and opportunities of small-scale farmers in Burkina Faso and Senegal

Judith Henze[1], Bright Little-Tetteh[2]

[1]*Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Germany*
[2]*L'Institut Agro, France*

Transforming local food systems is a complex process that requires a comprehensive understanding of the current status of existing systems, as well as producers' perceptions of their challenges and potential solutions. The NUTRiGREEN project is aimed at exploring and improving the value chains of healthy and sustainably produced traditional plants in order to integrate them into the diets and incomes of resource-poor people, and strengthen their impact on the food systems in Zitenga, Burkina Faso and Thies, Senegal. As a foundational step, the project conducted a household survey, interviewing 210 main decision-makers in Burkina Faso and 204 in Senegal. The objective of this survey was to identify current practices, barriers, and potentials in the two project regions.

This article presents the core findings of the survey, which include an analysis of current farming practices and decisions made by local farmers in the research areas. The study compares the production of cereals, cash crops, roots and tubers, vegetables, fruits, and trees between the two countries, while emphasising the key factors that influence farmers' production decisions. A special focus is placed on showcasing the agroecological practices that are already being followed, with an emphasis on the production, perception, and use of traditional plants, many of which have great potential in terms of nutritional security and medicinal properties. Furthermore, the article highlights the benefits of crop and dietary diversity, focusing on some of the indigenous plants being consumed in West Africa.

The study also includes an analysis of the information channels used by farmers, with the goal of establishing improved support and communication strategies to promote locally adapted sustainable resources management approaches. In addition, the article sheds light on the main perceptions and adoption methods chosen by small-scale farmers to address climate change.

Overall, this study provides valuable insights into the current status of local food systems in Burkina Faso and Senegal and highlights the challenges and opportunities for improving these systems in a sustainable manner. The findings of this study are relevant to policymakers, researchers, and practitioners working in the areas of food security and sustainable agriculture in West Africa and beyond.

Contact Address: Judith Henze, Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Robert-Koch-Platz 4, 10115 Berlin, Germany, e-mail: judith.henze.1@hu-berlin.de

Determinants of organic fertilisers utilisation among smallholder coffee farmers in Vietnam

Phuong Anh Nguyen, Miroslava Bavorová, Ayat Ullah

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

The Vietnamese coffee industry has achieved a high yield due to the excessive use of synthetic fertilisers in farming systems. It, however, had a detrimental effect on the environment. Since the industry is a crucial player in the country's socioeconomic development, it must be maintained sustainably. This study aims to increase organic fertiliser adoption among Vietnamese coffee growers by identifying the factors influencing the selection of organic fertilisers. Together, it addressed a connection between the use of organic fertiliser and the participation of farmers in the credit program. A bivariate model regression was used to estimate this linkage, relying on the data set using multistage sampling techniques. 139 Robusta coffee farmers were gathered from major coffee-growing areas in Dak Lak province in 2022, namely Buon Ky, Ea Tu, Ea Kao, Hoa Thang, and Ea Tieu. This data set also considered the mixture of minority and majority groups to determine the differences in their preferences for organic fertilisers and credit. Results indicate that variables of coffee farming experience, farmer membership, soil quality perception, and intercropping have a positive and significant effect; however, age and coffee farm size reduce organic fertiliser adoption. Other findings reveal that family and coffee farm sizes positively influence credit participation. Coffee farmers who adopt organic fertilisers and perceive better soil improvement were found to need less credit than those who did not perceive the benefit of using organic fertiliser. The study recommended that policymakers should focus more on a group of only chemical-fertiliser farmers and promote cooperatives and companies using organic fertiliser.

Keywords: Credit, farmer membership, organic fertiliser, robusta coffee, Vietnam

ID 901

Assessment of cropping systems and net economic returns in three agroecosystems of southern Myanmar

Phyu Thaw Tun, Zikrullah Safi, Andreas Buerkert

University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

Cropland expansion in the Kyunsu Township of Southern Myanmar has diminished natural forests and led to a decline of ecosystem services. To assess options for reducing production constraints and increasing net income on current cropland, a field survey of 301 households inhabiting three agroecological zones of the township: the plantation zone (15 % of households), the lowland zone (35 % households), and the sea zone (50 % of households), was conducted in 2020, and addressed characteristics of cropping activities. To identify types of cropping systems in each zone, the data were analysed by applying hierarchical clustering of principal components. The analysis revealed three types of cropping systems in each zone. The plantation zone consisted of a low productive system with limited input use (Type 1) and the high productive systems with limited (Type 2) and intensive input use (Type 3). These types (perennial-based) were the most beneficial as indicated by a gross value added (GVA, ha^{-1} yr^{-1}) of US\$ 746 (Type 1), 1693 (Type 2), and 1838 (Type 3). The same GVA tendency was observed for the three lowland zone types (rice-based): the low productive systems with intensive (Type 1) and limited (Type 2) input use and a high productive mixed (rice-perennial based) system with limited input use (Type 3), which hold a respective GVA of US\$ 141, 276, and 470 ha^{-1} yr^{-1}. In the sea zone, Type 1 (low productive perennial-based system with limited input use), Type 2 (high productive perennial-based system with intensive input use), and Type 3 (low productive rice-based system with intensive input use) were identified and yielded a GVA of US\$ 528, 695, and 232 ha^{-1} yr^{-1}. The most common production constraints across the observed cropping systems were poor soil quality, high input price, water scarcity, labour scarcity, unavailability of assets, inaccessible technology, lack of improved varieties, pest and disease infestation, and saltwater intrusion. To compensate production declines, farmers in the lowland and sea zones with lower land productivity may increasingly clear natural forest land for expanding their production. Resolving farmers' apparent production constraints may improve land productivity, increase household crop income, and help to sustain ecosystem services.

Keywords: Agroecological zones, cropping types, Kyunsu Township

Contact Address: Phyu Thaw Tun, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstrasse 19, 37213 Witzenhausen, Germany, e-mail: phyuthaw25@gmail.com

Balancing trade-offs and achieving synergies: The case for joint adoption of conventional and agroecological farming in Tanzania

Haji Athumani Msangi[1], Martha Swamila[2], Ntengua Selemani Mdoe[1], Anthony Kimaro[2], Katharina Löhr[3], Stefan Sieber[3], Betty Waized[1], Daniel Ndyetabula[1]

[1]*Sokoine University of Agriculture, Agricultural Economics and Agribusiness, Tanzania*
[2]*World Agroforestry (ICRAF), Tanzania Country Programme, Tanzania*
[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Climate change is one of the greatest global challenges of the 21st century. Its adverse effects on global agricultural production and food systems pose significant threats in Sub-Saharan Africa, where poverty, rapid population growth, and food insecurity are already prevalent. To address this issue, agroecological farming approach have been considered a viable solution. It ensures sustainability in agri-food systems while mitigating the impacts of climate change. However, concerns arise regarding the ability of agroecological farming to replace conventional external input farming to meet productivity and food security objectives, especially in Sub-Saharan African nations where agricultural productivity remains low, and food systems are unstable. This study is conducted in Tanzania to investigate the synergies between conventional and agroecological farming practices using the Tanzania's national panel survey (NPS) for the 2020/2021 wave. The study employed Multinomial Endogenous Treatment Effect (METE) regression to determine how the joint adoption of both approaches could improve farm productivity and food security in a sustainable manner compared to their separate implementation. The study reveals that combining conventional farming practices (inorganic fertiliser and agrochemicals) with agroecological farming practices (organic manure and agroforestry) can significantly enhance farm productivity and food security, indicating that the two approaches have a strong synergy. Interestingly, exclusive adoption of conventional farming can improve farm productivity and food security, but the magnitude of this effect is almost the same as that of the joint adoption of both approaches. In contrast, exclusive adoption of agroecological farming has a positive but insignificant effect on farm productivity and food security. These findings suggest the potential benefits of balancing the trade-offs of conventional high external input farming by adopting agroecological farming. Combining the two approaches can

Contact Address: Haji Athumani Msangi, Sokoine University of Agriculture, Agricultural Economics and Agribusiness, Sua, 67125 Morogoro cbd, Tanzania, e-mail: hajimsangi91@gmail.com

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help achieve productivity and food security objectives while protecting the natural agroecology. Therefore, the study emphasises the need for promoting policies and initiatives that encourage the joint adoption of conventional and agroecological farming practices to achieve sustainable and resilient agricultural production and food systems in Tanzania. However, such policies and initiatives must be complemented by other measures like credit access, extension, and social protection to enhance their adoption and impacts.

Keywords: Agro-ecological farming, Climate change, conventional farming, farm productivity, food security, METE, Synergies, Tanzania

Possible pathway and interactions for integrating mechanisation into sustainable rice production in Ghana

Selorm Y. Dorvlo

University of Ghana, Dept. of Agricultural Engineering, Ghana

Environmentally sustainable small-scale rice production mechanisation is a feasible intervention to help enhance yields and reduce food insecurity challenges. In Ghana, agricultural production is a significant component of Ghanaian livelihood and is an important economic activity for most of the population. Therefore, mechanised rice production can provide financial gains for small-scale farmers and ensure a sustainable agricultural production value chain based on practical agroecological principles. This study evaluates machinery ownership models and proposes the stakeholder interactions needed for sustainable rice production. The study uses primary data from a field survey of 320 farmers within Asutsuare, a rice production hub in Southern Ghana, key informant interviews with major stakeholders and secondary data from various sources. Findings show that some machinery ownership models can provide the smallholder rice farmer with the machinery needed to mechanise their production effectively. Four main machinery ownership models have been proposed and evaluated. The cooperative-owned machinery model, with a sharing of the initial investment capital outlay for the machinery acquisition, and the ownership model, where the farmer owns and offers hiring services to other farmers, were the most economically viable models. In addition, the study identifies necessary stakeholder engagement and interaction pathways to ensure the availability of innovative and affordable machinery at scale for locally appropriate and sustainable mechanised rice production. In addition to the benefits of releasing effective and good quality farm labour, the mechanisation model promotes machinery ownership that socially integrates machinery usage into the community and promotes the social aspects of resilient farming systems.

Keywords: Agroecology, rice production, stakeholder interactions, sustainable mechanisation

Contact Address: Selorm Y. Dorvlo, University of Ghana, Dept. of Agricultural Engineering, Legon, Accra, Ghana, e-mail: sydorvlo@ug.edu.gh

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Trends and determinants of change in rice-based production systems in the zambezi floodplain in Zambia

Owen Machuku, Mathias Becker, Kai Behn, Shyam Pariyar

University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany

With the second national rice development strategy from 2016, the Republic of Zambia aimed at increasing rice yields, expanding the cultivated area, and promoting agricultural innovations. Simultaneously, climate change increases risk for rice-based cropping systems in form of floods and droughts. Farmers may be affected differently depending on the positions of their fields along hydrological gradients in a floodplain. Opportunities and risks from policy and climate change may drive farmers to intensify or diversify their production systems. Thus, the resulting emergence of new cropping patterns and associated practices may require changes in input use and crop management practices. The study therefore aims at answering the following questions: What are current and likely future change trends in agronomic practices and yield? What are likely causes and drivers of change in the rice-based production systems in the Zambezi floodplain in Zambia? Through a diachronic household survey (comparing the year 2023 with 2013) we examined change trends from 40 farms on rice-based cropping systems in the Zambezi floodplain in the Western Province, Zambia. Survey data, including information on cropping practices, yields, and risk perception, was complemented by field observation and soil samples. The survey was stratified based on the hydrological gradient in the floodplain considering the flood-prone riparian zone, the favorable middle zone, and the drought-prone fringe, as well as irrigated rice fields. Soils in all zones were acidic with an average of pH 4.3. Total N was about 0.15 % with CN-ratio ranging from 10-14. Farmer´s attributes, farmer´s resource endowment, rice grain yield, and production constraints differed along the hydrological gradient. In 2023, almost all farmers had access to extension service (75 % in 2013), yet farmer´s access to inputs and machinery remain low. Rice yields ranged in 2013 from 0.9 t ha^{-1} (drought prone zone) to 2.39 t ha^{-1} (irrigated fields) and from 0.71 t ha^{-1} (submerge prone zone) to 1.74 t ha^{-1} (irrigated fields) in 2023. To sustainably intensify rice production, site-specific conditions must be considered. We foresee the need for mechanizing the rice production, linking farmers to markets, supporting farmers with farming inputs and extension of irrigation infrastructure.

Keywords: Agriculture policy, diachronic analysis, diversification, *Oryza sativa*

Contact Address: Owen Machuku, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Endenicher Allee 17, Bonn, Germany, e-mail: s7owmach@uni-bonn.de

Adoption potential for sustainable small-scale irrigation with solar pumps in Burkina Faso

Hycenth Tim Ndah[1], Johannes Schuler[1], Edmond Rouamba[2],
Pingwinde Marc Ouedraogo[3], Bruno Barbier[2]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Farm Economics and Ecosystem Services, Germany*

[2]*Agricultural Research Centre for International Development (CIRAD), UMR G-Eau, Burkina Faso*

[3]*Action for the Promotion of Entrepreneurship and Irrigation Systems, Burkina Faso*

Farmer led irrigation (FLI), is expanding rapidly in Africa, particularly in Burkina Faso, where thousands of farmers mobilise water from close-by water sources in the dry season or during dry spells of the rainy season. Further expansion of irrigation is limited by often painful, inefficient, or unsustainable practices. However, there are several promising innovations, developed by farmers themselves, by private firms or by research and development agencies, which are often unaffordable or poorly adapted. Barriers to the adoption of such innovations are not only financial, but also technical, social, and organisational. As part of the IRRINN project (www.irrinn.org), this contribution focuses on small scale irrigators, and their attitude towards solar pumps. With the aim of determining the adoption likelihood of these pumps, we explored the innovation environment, identified and analysed drivers and constraints to adoption, as well as proposed actions for further promotion. Methodologically, a variant of the QAToCA research tool called QAT'RRINN, has been applied in four villages around Ouagadougou, where over 30 stakeholders provided detailed input on the tool's indicators in a participatory workshop. Findings revealed inhibiting factors from the participants' perceptions such as limited knowledge and funding, difficulties in accessing inputs, the limited duration of the promoting organisation's engagement, and weak dissemination support from local private organisations. Also, the lead-farmer approach was not used, while technically, the minimum plot size required could hinder adoption. Supporting factors for adoption are easy integration into the existing agricultural system since farmers are already experienced with irrigation. At the organisational level, it is appreciated that the implementing organisation works well with project partners and disposes of qualified staff. Furthermore, the innovation is compatible with the local context and does not face resistance from neighbouring farmers. We recommend accompanying up-scaling by providing technical information through extension, facilitating access to related inputs, and enhancing access to financial resources (e.g., loans and subsidies). The study underlines the importance of observing the whole context of an innovation's environment, not only focussing on its technical performance. Results of this study can help to overcome adoption obstacles or even question its appropriateness in the local context.

Keywords: Adoption, innovation, irrigation, small-scale agriculture, solar pumps

Contact Address: Johannes Schuler, Leibniz Centre for Agric. Landscape Res. (ZALF), Farm Economics and Ecosystem Services, Muencheberg, Germany, e-mail: schuler@zalf.de

Identifying and predicting best-performance cases to foster a sustainability transition in West African cocoa production

Jens Van Hee, Franziska Ollendorf, Claudia Coral, Stefan Sieber, Katharina Löhr

Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany

Over the past decade, in West African cocoa production, efforts to deliver trainings on more sustainable production techniques have been undertaken by various public and private actors. These interventions mostly combine trainings on 'Good Agricultural Practices' (GAP), and, more recently, also comprise aspects of on-farm diversification and agroforestry (AF). While up until now there is little knowledge to what extend these interventions show effect on the actual farmer income and farming practices, success still seems to be limited since poverty is still highly prevalent. However, while most cocoa farmers struggle under the given conditions of their enabling environments, there are farmers facing similar conditions that manage to outperform their peers, using creative and local solutions.

The proposed contribution assesses the existence of cases of such positive deviance among cocoa farmers in Côte d'Ivoire. In backdrop of the Living Income benchmark, and following the Positive Deviance approach, four dimensions of performance are measured: farmers' cocoa income, their socio-economic situation, the degree of income diversification, and the amount of GAP and AF practices applied on the cocoa farm. Based on a survey conducted in 2022 among 303 cocoa farmers in five regions in Côte d'Ivoire, best performers are identified by comparing absolute performance with the performance that would be predicted given the farmers' enabling environment. The difference is combined in one relative performance vector for each farmer, and then used to calculate the Pareto optimal. As such, farmers are identified that outcompete their peers in all three dimensions, and seem to be dealing with trade-offs successfully. In-depth interviews are then conducted with positive deviant farmers to identify reasons for outperformance.

The objectives of the study are twofold: first, it is aimed to identify and predict cases of positive deviance among Pro-Planteurs targeted cocoa farmers and second, to understand the reasons for their better performance. The findings help to provide lessons for future interventions aiming to create better conditions for farmers' performance and for scaling-up locally tailored interventions.

Keywords: Cocoa, Côte d'Ivoire, positive deviance, sustainability transition

Contact Address: Jens Van Hee, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries
current address: Krogstraat 100, Meise, Belgium, e-mail: jpvhee.vanhee@ugent.be

Towards sustainable land management and agricultural practices in Central Vietnam: Challenges and opportunities

Sebastian Romuli[1], Andreas Aron-Winkler[1], Nguyen Thi Thu Thuy[2], Chu Manh Trinh[3], Joachim Müller[1]

[1]*University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany*
[2]*University of Economics Ho Chi Minh City, College of Business, Vietnam*
[3]*Cham Islands Marine Protected Area, Res. and Intern. Coop. Div., Vietnam*

Agriculture is a key development sector in Vietnam, in which significant sustainability gains could arise from its nexus with growing cities and other development sectors, such as emerging rural tourism. To address the sustainability of agricultural practices, a survey of 30 smallholder farmers of Cu De River Valley in the Da Nang region was conducted following a standard methodology based on the Original Agroecology Survey and Indicator System (OASIS). Fruits and vegetables were mostly produced through agroecological practices while rice, sugar cane and corn were mainly cultivated in a conventional way. The higher workload needed to apply organic fertilisers was the main barrier in the transition to organic fertilisation management. The soil was left uncovered, which reduced the water absorption capacity of the land, and the residues were burned, which polluted air and water streams and affected rural communities and farmers in the surrounding area. Conventionally produced commodities were the main sources of income and they were sold mostly through intermediaries that bought most of the production, leading to a double dependency of one main product and one main client. Those products were also more affected by the increasing costs of mineral fertilisers that tripled in the past two years, leading to a reduction in profits. Furthermore, soil degradation was reducing productivity and the farmers were looking for alternatives such as diversifying their production from sugar cane and rice to a mixed system of fruticulture with livestock. The participants also suggested several strategies to enhance sustainability, such as direct selling of products which could increase the selling price by up to 87.5 %. For instance, in the case of peanut oil production, postharvest processing, such as drying, pressing, and packaging, led to a 30 % increase in profits. During the survey, the potential benefits of integrating agriculture and forestry with tourism, as a means of promoting sustainable agricultural practices, were also noted.

Keywords: Agroecosystem, cooperative, environmentally friendly

Contact Address: Sebastian Romuli, University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Garbenstr. 9, 70599 Stuttgart, Germany, e-mail: sebastian_romuli@uni-hohenheim.de

Banana food-fibre nexus: The position of Uganda's banana smallholder farmers

Daphine Kamusingize[1,3], Esther Ronner[1], Godfrey Taulya[2], Priver Namanya[3], Jerome Kubiriba[3], Katrien Descheemaeker[1]

[1]*Wageningen University & Research, Plant Production Systems Group, The Netherlands*
[2]*International Institute of Tropical Agriculture (IITA), Uganda*
[3]*National Agricultural Research Organization, Nat. Banana Res. Progr., Uganda*

Globally, there is growing interest to utilise agricultural residues as raw material in diverse industries, including use of banana stems for production of natural fibre. Uganda, where over 80 % of farming households grow bananas for food and income, is gearing up its fibre production to tap into the growing demand. However, successful scaling up of fibre production depends on the feasibility of banana farmers, as potential raw material producers, to re-orient from production of banana as a food crop to a commercial crop with multiple uses e.g. fibre. This could pose negative implications at farm level, on their food self-sufficiency, income and nutrient balances. This study assessed, from the stakeholders perspective, the underlying socio-economic factors motivating farmers' engagement in fibre production, and the potential implications on their livelihoods. Data were obtained through a systematic set of mixed methods. Out of 8, stakeholders ranked market-access, good agronomic management, social group affiliation and access to alternative nutrient sources as the most important attributes to motivate farmer engagement in fibre production. Overall, resource-endowed farmers belonging to a farmer group, with diverse information sources, more livestock and implementing 100 % of recommended agronomic practices were better positioned to engage compared to those resource-constrained. These resources support the current fibre production demands; e.g., quality of stems produced, but could also help mitigate the potential risks therein. Averagely, all households were food self-sufficient with 7,635–10,149 kcal^{-1}day per adult male equivalent, with banana contributing the most. Average annual household incomes were 833–2,320 USD. Returns from selling all stems harvested could increase incomes by 6–10 %, benefiting mostly the resource-constrained farmers. The proportion of households that were food self-sufficient could however reduce from >80 % to ≤30 % assuming a reduction in banana food production resulting from harvesting stems for fibre before horticultural maturity of bunches. This could also lead to a 40 % reduction in income originally obtained from selling bunches. The increasing global fibre demand offers farmers new income opportunities from the sale of stems. Long term solutions are however required to minimise the potential trade-offs of upscaling fibre production at farm level on the livelihoods of banana-dependent communities.

Keywords: Diversification, East Africa, natural fibre, smallholders, trade-offs

Contact Address: Daphine Kamusingize, Wageningen University & Research, Plant Production Systems Group, Bornsesteeg 48, 6708PE Wageningen, The Netherlands, e-mail: daphine.kamusingize@wur.nl

Changing trends in management practices and their implications for production under different rice-based systems in coastal Bangladesh

Md Amirul Islam[1], Shyam Pariyar[1], Timothy J. Krupnik[2], Mathias Becker[1]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*
[2]*International Maize and Wheat Improvement Center (CIMMYT), Sustainable Intensification Program, Bangladesh*

The predominant rice-based systems in coastal areas of South and Southeast Asia are at risk by effects of climate change and tidal salt intrusion. The combined external and internal factors influence farmers to intensify or diversify their production systems. Thus, the resulting emergence of new cropping patterns and associated practices may require changes in input use and crop management practices. We aimed to understand current and likely future change trends in agronomic practices and yield, and to identify likely causes and drivers of change. Through a diachronic household survey (comparing 2021 with 2011) in two contrasting coastal districts of southern Bangladesh i.e., i) marginal & saline, and ii) more favourable, we examined change trends from 240 farms in three rice-based cropping systems: (1) extensive rice-fallow, (2) intensified double rice, and (3) diversified rice-mungbean rotations. Survey data were complemented by soil samples for physio-chemical attributes analysis. Results reveal that recent change trends concern mainly the mechanisation of tillage operations and increased application rates of mineral fertilisers. Such changes were more at the favourable sites (61 % of farmers shifting to mechanisation and 63 % increasing fertiliser application rates) than at the marginal site (18 % increase in mechanisation and 36 % in fertiliser use). The three cropping systems also differed, with largest variations in mechanisation levels in intensive double cropped, and highest diversity in fertiliser use in single rice and diversified systems. Change trends in agronomic practices were more in the dry than in the wet season, irrespective of the site. Despite notable differences in agronomic practices, rice yields did not differ significantly between season and sites. However, yield (rice equivalent) variability, and thus the uncertainty in the outcome of farmers' investments, was higher in the dry than in the wet season, with rice yields of 3.5–7.8 t ha^{-1} and mungbean yields of 1.0–4.1 t ha^{-1}. The study highlights that recent change trends differ between sites and seasons, while the resulting yields and yield variabilities differ mainly between seasons and production systems. Consequently, there is a need for site, system, and season-specific assessments of change trends and their implications in coastal rice production areas.

Keywords: Diversification, intensification, mechanisation, *Oryza sativa*, salinity, *Vigna radiata*

Contact Address: Md Amirul Islam, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Karlrobert-Kreiten-Str. 13, 53115 Bonn, Germany, e-mail: ma.islam@uni-bonn.de

ID 709

Local agricultural innovation system for rural producers in Consolación del Sur, Pinar del Río, Cuba

Raymundo Vento Tielves[1], Evelyn Pérez Rodríguez[1], Bettina Eichler-Löbermann[2], María Mercedes González Hernández[1], Reina María Rodríguez García[1], Belkis María Pelegrín González[1], Iracely Milagros Santana[1], Daileen Caro Sánchez[1]

[1]*University of Pinar del Río, Center for Environment and Natural Resources Studies, Cuba*
[2]*University of Rostock, Agricultural and Environmental Faculty, Germany*

The research developed inserted in the DiveCropS Project: Diversifying Cropping Systems financed by DAAD of Germany, in the región of Consolación del Sur, in Pinar del Río province, in Cuba. In this región the use of inappropriate technologies has caused serious damage to agricultural production, decreasing yields and limiting food production, decreasing yields and limiting food production, and Limited integration of rural actors in carrying out production, transformation and marketing processes significantly limits the productive results of family farming farms. In response to this problem, the objective of Implementing a Local Agricultural Innovation System (Sial) is outlined in order to achieve synergy between rural producers for greater agricultural productions in the Consolación del Sur municipality. The research methodology used begins with a Diagnosis of the model of agricultural production, Study of the Climatic changes in the región, Study to management of soil and wáter and other indicators. The results achieved allow us to demonstrate that the characteristics of the agricultural context in the Consolación del Sur municipality show marked potential in productive systems with a high range of diversity and with an important vocation for the development of local enterprises of high productive value, but do not achieve full development. of their capacities due to the insufficient integration between rural actors. The implemented Local Agricultural Innovation System allows achieving greater synergy and integration between rural producers that allows a closure of the processes from production, transformation and commercialisation, the actions proposed in the innovation system presuppose a comprehensive management approach with training, integration of rural actors and social participation, as essential elements within the process of knowledge management and technological innovation, reaching the closure of productive processes of agroecological techniques, agroindustry and commercialisation

Keywords: Agricultura, agroecología, agroindustria, innovación agrícola

Contact Address: Raymundo Vento Tielves, University of Pinar del Río, Center for Environment and Natural Resources Studies, Borrego Avenue Building 108 Apt C-9 Brothers Cruz, 20100 Pinar del Río, Cuba, e-mail: tielve@upr.edu.cu

Assessment of diversification strategies on level of living among soybean farmers in Kaduna State, Nigeria

Adam Mohammed[1], Yusuf Oladimeji[2], Bashir Magaji[1], S. A. Makama[1], Ado Yakubu[1], Abubakar Sani[1], Sanni Abdulrahman[1], Aisha Husseini[1]

[1] *AFEX Commodities Exchange Limited, Risk, Audit and Assurance, Nigeria*
[2] *Ahmadu Bello University, Zaria, Dept. of Agricultural Economics and Rural Sociology, Nigeria*

On-farm diversification refers to the shift from primary agricultural produce to diversifying economic outputs within the agricultural sector. Increasing the productivity of the agricultural sector has significant multiplier effects in stimulating other sectors of the rural economy. The study was designed to assess the effect of on-farm diversification strategies on output and level of living among soybean-based cropping farmers in Kaduna State, Nigeria. Primary data was collected from 336 soybean-based cropping farmers with the aid of a structured questionnaire. The livelihood diversification index and ANOVA statistics were used to achieve the study's objectives. The result of the distribution of the soya bean farmers showed that, about (80.5 %) male were involved in soya bean based cropping system. This could be attributed to the fact that men are mostly involved in crop production in the study area as women are mostly play a supportive roles such as taking part in planting and harvesting and post-harvest handling of harvested crops. Soybean crop farmers engaged in soybean/maize- (36.7 %), soybean/cowpea- (25.2 %), soybean/sorghum- (24.6 %) based and sole soybean (13.5 %) cropping systems. Results show that majority of the rural households (69.6 %) diversified their livelihoods into several activities and earned significant amount of income from multiple sources. Only 30.5 % of households had less than 0.01 on the Simpson index, thus depending on only one source of livelihood activity. On-farm income was the highest income sources contributing 73.4 % of the total mean share of the income of the farmers with a significant difference ($p < 0.001, \chi^2 = 31.98$) between the on-farm, off-farm and non-farm earnings. This implied that on-farm income had significant impact on the level of living among soybean based cropping systems in Nigeria. Government policy needs to focus on access to arable land and extension support targeted at rural households to promote diversification to on-farm activities. Since the production of soybean and its diversification is skewed towards male folk, Paying attention to the creation of gender-sensitive opportunities and removal of gender bias and discrimination within communities, to allow female households to diversify their income.

Keywords: Income, livelihood diversification, Nigeria, soybean

Sustainable land use, food systems, and commodity chains in regions of climate vulnerability, deforestation, and conflict

Effectiveness of cocoa cropping systems to reduce deforestation in Colombia's post-conflict areas

Miguel Romero[1,2], Marcos Lana[2], Augusto Castro-Nunez[1], Marcela Quintero[1]

[1]*The Alliance of Bioversity International and CIAT, Multifunctional Landscapes, Colombia*
[2]*Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden*

The agriculture, forestry, and other land use sectors are the first source of greenhouse gas (GHG) emissions in Colombia, accounting for more than 50 % of the total. Emission sources include land use change from forest to crop/grassland, enteric fermentation by livestock, manure handling, and rice cultivation. Agricultural expansion is the main driver of deforestation in Colombia, and the government is committed to reduce GHG by 30 % by joining global efforts to achieve deforestation-free production.

Cocoa cultivation is promoted as an economic alternative in post-conflict areas despite a lack of evidence and understanding of the role of such interventions in reducing deforestation. The aim of this work is 1) to establish the spatial distribution of cocoa farming systems in the Caquetá region and 2) to establish if the presence of cocoa farms are associated with deforestation.

From a list of 2353 farmers in the region obtained from with local authorities, growers' associations and federations, and technical assistance offices, 448 farmers (19 %) were randomly selected for detailed spatial data collection using the Collector tool of the ArcGIS software data. Land cover use and forest and cocoa cropping areas were identified using satellite images. Correlations and spatially explicit analyses were performed to explore to what degree cocoa production is associated with deforestation using official spatial data on forest loss.

Results show that 60 % of the farms have been associated to deforestation during the last 20 years, with most of the forest losses occurring in the 2012–2020 period. When looking specifically at the cocoa production areas within the farms, 20 % of cocoa cropping areas are associated with deforestation. Using data from semi-structured interviews with the same farmers, 32 % of the cocoa farms planted cocoa tress in deforestation areas. As the implementation of new cocoa production areas was supported and implemented in the framework of national and international initiatives, our findings indicate that the promotion of cocoa cultivation needs to be done taking into account the risk of promoting deforestation. Therefore, such initiatives must be addressed and co-designed with different actors in each specific context to avoid deforesting new areas to plant cocoa.

Keywords: Agroforestry, climate change mitigation, sustainable supply chain, zero deforestation

Contact Address: Miguel Romero, The Alliance of Bioversity International and CIAT, Multifunctional Landscapes, Km 17 Cali Palmira, Cali, Colombia, e-mail: m.a.romero@cgiar.org

Boosting the adoption of sustainable land-use systems for climate-change mitigation and peacebuilding

Lisset Perez-Marulanda[1,2], Martin Rudbeck Jepsen[1],
Augusto Castro-Nunez[2]

[1]*University of Copenhagen, Denmark*
[2]*The Alliance of Bioversity International and CIAT, Colombia*

Sustainable land-use systems (SLUS), such as agroforestry with cocoa, implemented with organic fertiliser, with prescribed post-harvest practices and rainwater irrigation, can potentially increase farm productivity, while reducing pressure on natural resources by decreasing deforestation and providing legitimate incomes for rural households. SLUS also contribute to peacebuilding by providing sustainable income sources and enhancing social cohesion. Despite evidence of their potential and global efforts to promote their use, SLUS adoption rates remain low. Building on traditional ex-post generic adoption studies, we identify the enabling factors for farm-level transitions to SLUS in Colombia to propose policy design that will boost SLUS adoption in areas that are conflict affected and exposed to deforestation. We surveyed a sample of 922 cocoa producers in conflict-affected areas prone to deforestation. To reveal SLUS adoption factors, we (i) classified farmers according to number of sustainable methods applied; (ii) estimated an ordered probit econometric model; and (iii) assessed existing policies to promote cocoa production systems in Colombia, comparing their alignment with the adoption factors identified. We find a mismatch between farm-level adoption factors and policies promoting SLUS in Colombia. The principal factors enabling farm-level adoption of sustainable cocoa production system depend on: (i) cocoa plantation age; (ii) technical assistance provided; (iii) farmers' social networks; and (iv) farmer-to-farmer interaction. National policies to promote sustainable cocoa are mostly oriented towards (i) renewing and rehabilitating established farming areas (directly related to crop age); (ii) expanding cocoa agroforestry systems; and (iii) establishing zero-deforestation cocoa production agreements. Our results indicate that to achieve wide-scale SLUS adoption, policies should focus on: (i) capacity building through technical assistance and strengthening farmers' associations; (ii) strengthening social network structure to generate cascading information and social interactions between producers, and knowledge sharing; (iii) land-use conversion instead of expansion, for example from pastures to cocoa.

Keywords: Agroforestry, climate change mitigation, equity, peacebuilding

Contact Address: Lisset Perez-Marulanda, The Alliance of Bioversity International and CIAT, Low Emission Food Systems, Kl 17 recta cali palmira Colombia, 760020 Cali, Colombia, e-mail: lisset.perez@cgiar.org

ID 158

Toward zero deforestation value chains: environmental upgrading and downgrading among non-certified cocoa producers in Colombia

Ma. Villarino[1], Marianne Nylandsted Larsen[1], Augusto Castro-Nunez[2], Mary Eyeniyeh Ngaiwi[2]

[1]*University of Copenhagen, Dept. of Earth Science and Nature Management, Denmark*
[2]*The Alliance of Bioversity International and CIAT, Colombia*

Global pressure to make value chains less damaging to the natural environment, a process known as environment upgrading, has been building in recent years. Most studies that assess environmental upgrading have focused on the compliance of suppliers, which would be farmers in the case of value chains involving agrifood commodities, to sustainability certification standards. Our case study focusing on cocoa producers in Colombia explores an under-investigated topic in environmental upgrading — that of whether sustainable practices of non-certified farmers facilitate zero-deforestation value chains. Using data from 930 randomly sampled households in the Colombian departments of Caqueta and Cesar, we examined the association of non-certified sustainable practices, i.e., processes that benefit the environment which farmers undertake on their own and not because of adherence to sustainability certification criteria, with reforestation and deforestation: A positive association of the practices with the former suggests environmental upgrading, while with the latter would be environmental downgrading, which denotes negative environmental outcomes from the process of environmental upgrading. We also assessed whether or not there are significant differences between mean deforestation and reforestation rates between certified and non-certified cocoa producers in both departments. Based on statistical tests, we found that (a) non-certified sustainable practices can facilitate environmental upgrading and discourage environmental downgrading but only in some cases, and (b) there is no significant difference in mean deforestation rates between certified and non-certified surveyed cocoa producers, but there is a significant difference in mean reforestation rates between the two groups of producers. These results suggest that implementing non-certified sustainable practices poses another way to enable value chain actors to meet the requirements in markets seeking sustainably produced commodities. One such market is that of the European Union, whose legislation on deforestation-free commodities makes certification an optional rather than compulsory process to support the prescribed procedure on diligence procedure.

Keywords: Agroforestry, environmental downgrading, environmental upgrading, sustainable agrifood systems, Sustainable value chains, zero deforestation

Contact Address: Ma. Villarino, University of Copenhagen, Dept. of Earth Science and Nature Management, Rolighedsvej 23, 1350 Copenhagen, Denmark, e-mail: e.villarino@cgiar.org

Promoting environmentally and socially responsible global supply chains

Laura Krings, Lioba Schwarzer, Elke Mannigel

OroVerde - Die Tropenwaldstiftung, Germany

Biodiversity conservation and climate change migitation are main challenges for the safeguarding of livelihoods and human security and the functioning of the world's ecosystems. Forest conservation and restoration make a remarkable contribution, regarding their importance for valuable ecosystem services and global carbon storage. Planting trees has become a popular and seemingly easy medium to implement this approach. However, it has become clear that planting trees is not a panacea since deforestation is still too high, due to the ongoing lack of incentives in the global economy. OroVerde - Tropical Forest Foundation provides a holistic view on forest conservation and restoration and identifies ways to make our way of life environmentally and socially more responsible. In this sense, global supply chains are one important focus: Many products consumed in Europe (e.g. coffee, cocoa, palm oil) come from tropical countries while their cultivation is one of the main deforestation drivers. Two upcoming policy instruments address the problem in the EU: the EU-Deforestation Regulation and the Corporate Sustainability Due Diligence Directive. However, these regulations raise challenges for both smallholder farmers and companies.

OroVerde uses multiple levers to tackle this problem: at the local level, the work's focus is on smallholder farmers in Central America. Strengthening policy frameworks, improving access to financing, and providing organisational development of farmer associations facilitates market access, even to Europe, to farmers with sustainable production methods contributing to the restoration of ecosystems, rather than to deforestation. The main goal ist to foster incentives to conservation in producer countries.

On the private sector level in Germany, the focus is on awareness and transition in companies. By the means of an online platform „ELAN", companies are supported on how to eliminate deforestation from their supply chains, thus implement the regulations, but at the same time benefitting smallholder farmers and contributing to a sustainable global economy. By conducting advocacy work, influence is exerted on the design of the laws in order to make them more environmentally and socially compatible, respecting the requirements of stable ecosystems, the rights of indigenous people and local communities and the livelihoods of smallholder farmers.

Keywords: Deforestation-free supply chains, ecosystem conservation, EU legal framework, forest landscape restoration, smallholder farmers

Contact Address: Laura Krings, OroVerde - Die Tropenwaldstiftung, Burbacher str. 81, 53129 Bonn, Germany, e-mail: lkrings@oroverde.de

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Narratives for the sustainability of agri-food systems in Ecuador: Understanding their divergences, similarities, and complementarities to catalyze transformative change

Tatiana Rodriguez, Heidi Wittmer

Helmholtz Centre for Environmental Research (UFZ), Dept. of Environmental Politics, Germany

Due to the expansion of large-scale and export-oriented agriculture and the depletion of ancestral knowledge, Ecuadorian agri-food systems are facing vicious cycles of environmental and social impacts that jeopardise their potential to ensure food and nutritional security for the growing population and contribute to global food production without depleting the natural and social capital. Transforming unsustainable agri-food systems requires alternative narratives to the status quo. Narratives are defined as storylines underpinned by frames to define problems, diagnose causes, and suggest solutions. In this sense, an analysis of narratives is critical to problematizing these vicious cycles within agri-food systems and identifying potential solutions. Therefore, this study aims to analyse the narratives of multiple stakeholders around the sustainability of the agri-food systems in Ecuador, to identify divergences, similarities, and complementarities among their underlying frames. The study employs the discursive agency approach (DAA), which has a particular focus on actors and their agency.

The study is reviewing policy documents and conducting semi-structured interviews with key stakeholders from Ecuador whose work is related to the production, transformation, commercialisation, or consumption of agricultural products. The data are coded into the categories provided by the DAA.

Two narratives have been distinguished based on preliminary analysis. One could be labeled neoliberal sustainable agri-food systems, which problematizes the current crisis as a lack of knowledge and innovation. According to this narrative, access could be granted through capacity building, investment, and/or bank loans, and the costs and risks of transition are addressed through contract farming or international certification. The other could be called local-oriented and culturally-embedded agri-food systems, which see the problems as a result of the colonial past, marginalisation, unequal access to land, and depletion of local knowledge. Under this narrative, access to healthy and nutritious food is put at the centre through solidarity economies, local markets, and trust-based certification. Although there is some overlap between the two narratives, the emphasis is quite different as the second goes well beyond changing the way food is produced, but also the way it is consumed. Both narratives involve different actors as agents of change and call for different institutional settings.

Keywords: Food security and nutrition, narratives, sustainable agri-food systems, transformative change

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Contact Address: Tatiana Rodriguez, Helmholtz Centre for Environmental Research (UFZ), Dept. of Environmental Politics, Genter Straße 8, 13353 Berlin, Germany, e-mail: tatiana.rodriguez@ufz.de

Analysing cacao productivity in agroforestry systems through the lens of social-ecological interactions: A comparison of two municipalities in Colombia

Maria Sofia Morales Guzman[1], Tatiana Rodríguez[2], Michelle Chevelev-Bonatti[3], Stefan Sieber[3]

[1]*Humboldt-Universität zu Berlin, Germany*
[2]*Helmholtz-Center for Environmental Research (UFZ), Germany*
[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Social ecological systems (SES) are composed of multiple ecological and social subsystems that continuously interact. The concept of complexity is embedded within their definition for which they are often regarded as complex adaptive systems (CAS). Cacao agroforestry systems (CAFS) are an example of SES, as they promote multiple interactions between cacao crop (*Theobroma cacao*) and ecological entities (wood, fruit, or cover species). CAFS provide a range of benefits such as habitat for biodiversity, and income for farmers. Therefore, they are a sustainable alternative to produce cacao, an important commodity for global trade and consumption. In Colombia, cacao is produced for the domestic market and has been managed by smallholder farmers under agroforestry systems, which counterbalances an expanding agricultural frontier that causes deforestation. But Colombian farmers often struggle due to a poor infrastructure, technical assistance, vulnerability to armed conflict, and face difficulties due to climate variability.

Therefore, understanding CAFS from a holistic perspective could support their adequate dissemination. However, their inherent complexity has challenged their study and there is much research focused on the relationships between specific components of the CAFS (percentage of shade, soils, pest management) and their productivity, failing to account for the various dimensions of sustainability. The objective of this study was to identify and analyse the socio-ecological interactions affecting CAFS productivity using a complexity approach. We conducted in-depth semi-structured interviews with 19 cacao farmers in two municipalities of Colombia: La Paz, and Belén de los Andaquíes. The interviews were transcribed and codified using the social-ecological action situation framework as a basis for data categorisation. Subsequently, we calculated centrality metrics to identify the most important interactions influencing CAFS productivity.

Results revealed 168 interactions that influence the productivity of cacao. In both regions, the interactions that have greater influence involve

Contact Address: Maria Sofia Morales Guzman, Humboldt-Universität zu Berlin, Invalidenstr. 42, 10115 Berlin, Germany, e-mail: maria.sofia.morales.guzman@student.hu-berlin.de

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farmers, cacao, soil, and traders. Furthermore, cacao productivity is linked to the ecological dimension through the interactions of soil-farmer and cacao diseases-farmer. Finally, results corroborated that the social dimension is fundamental for cacao productivity because actors like traders, and local associations play an important role, because they influence the continuation of agricultural activities which eventually shapes cacao productivity.

Keywords: Agroforestry, climate change mitigation, complex systems, peace-building, scaling, sustainable agriculture

Cocoa sustainable business models and poverty traps in rural areas of Colombia

Martha Lilia Del Río Duque[1], Marcos Lana[2], Michelle Chevelev-Bonatti[1], Miguel Romero[3], Tatiana Rodríguez[1], Augusto Castro-Nunez[3], Stefan Sieber[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

[2]*Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden*

[3]*The Alliance of Bioversity International and CIAT, Multifunctional Landsc., Colombia*

Cacao agroforestry systems with an organic management plan are promising sustainable solutions for fostering climate change mitigation and peacebuilding processes. Cacao crop in the country grows in regions with contrasting socioecological problems. According to ICCO, 95 % of their exports are recognised as fine or aroma cocoa. Despite this feature, almost 80 % of cacao production is purchased for a domestic market and without any certification or as bulk cacao. The current cocoa business model is dominated by middlemen who buy cacao beans in the pulp (en baba). This type of business leads to a poverty trap. In that vein, assessing promising sustainable business models and analysing poverty traps is crucial to the co-creating of economic profits, and social and environmental benefits in rural areas of Colombia.

We used a two-phase mixed methods design in two regions with significant potential, although contrasting, to promote cacao, Caquetá, and Cesar. Firstly, deploying a deliberative focus group methodology we did two regional discussion workshops with the cacao growers (approx. 50 farmers) in these two regions. Through these workshops, we analysed the consistency and effectiveness of a sustainable cocoa business model. For this purpose, we presented the producers' perspective on six sustainability indicators: income, costs, yields, associativity, knowledge generation, soil improvement, biodiversity, and robustness and stability in cocoa sales.

Secondly, we used a quantitative approach consisting of a household survey with 929 cacao growers in Caquetá and Cesar to elicit the effects of the type of business and sales channels on poverty and sustainability of cacao farming in these contrasting regions. The dependence on the intermediaries plays a huge role in the household decision-making process, as a result, it can determine whether the household falls into a cocoa growing sales channel –sustainable agriculture trap or falls out of it.

Results showed that for producers fermentation and drying on the farm, organic farming practices, genetic material suitable for the region, proper water management, and selling associatively to buyers involved in the development of more sustainable crop systems is the way to achieve positive changes in income, costs, yields, biodiversity, soils, and to overcome poverty traps.

Keywords: Agroforestry, business model, equity, sustainable supply chain

Contact Address: Martha Lilia Del Río Duque, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder Straße 84, 15374 Müncheberg, Germany, e-mail: Martha_Lilia.Del_Rio_Duque@zalf.de

Agrobiodiversity, resilience and food system change in the Andes

Stef de Haan[1], Karl Zimmerer[2], Andrew Jones[3], Hilary Creed-Kanashiro[4], Krysty Meza[4], Ochoa Javier[1], Milka Tello[5], Alejandro Diez[6]

[1]*International Potato Center (CIP), Andean Initiative, Peru*
[2]*Pennsylvania State University (PSU), Ecology and Rural Sociology Program, United States*
[3]*University of Michigan, School of Public Health, United States*
[4]*Institute of Nutritional Research (IIN), Peru*
[5]*Universidad Nacional Hermilio Valdizan (UNHEVAL), Peru*
[6]*Pontificia Universidad Catolica del Peru, Facultud de Antropologia, Peru*

The variability of species and varieties of food crops provides multiple provisioning, regulating and cultural ecosystems services within mountain food systems. The Andes are a well-known hotspot of crop, livestock, and wild edible diversity used for consumption and sales. This agrobiodiversity, its direct uses, and functions are affected by several changes and shocks, ranging from migration, markets, pests and diseases to extreme climatic events. The COVID-19 pandemic disrupted global, national and local food systems in multiple ways. To understand how it affected the agrobiodiversity-food nexus, we conducted a multidisciplinary assessment focusing on the production and use of agrobiodiversity before and after the pandemic. Data collection involved the same communities and households in 2017 and 2022 respectively. The study was conducted in the Huanuco highland region of Peru, involving rural households with young children. The study involved extensive assessments of agrobiodiversity, food intake and food environment in 3 distinct landscapes and 30 communities involving between 300 to 600 households depending on the method. Specific methods included participatory mapping, plot-level species and varietal sampling, a structured survey, food environment transects, a 24-hour dietary recall, focus group meetings, among others. Here we will present preliminary findings from the research and infer upon the effect of the pandemic on the conservation and use of agrobiodiversity. In parallel, we also explore the contribution of agrobiodiversity to the adaptive capacity of rural households. The implications for social protection, development and local food security programmes targeting vulnerable populations will be discussed considering current national and regional policies.

Keywords: Dietary diversity, genetic resources, landraces, Peru

Breaking the mold: Gender dynamics and sustainable agrifood systems adoption for low emission food systems

MARY EYENIYEH NGAIWI, JANELLE SYLVESTER, GEORGE AMANHUI

The Alliance of Bioversity International and CIAT, Colombia

Sustainable agrifood systems have the potential to significantly impact the livelihoods of smallholder farmers in Cameroon. However, there is a gender disparity in the adoption of these technologies due to various sociocultural norms and gender dynamics. In 2020, 351 southern and eastern Cameroonian farming households were surveyed. Gender roles, decision-making, and sustainable agrifood systems were studied using a multistage random sample. The principal component analysis identified thirteen sustainable agrifood systems used by farmers and grouped them into practices with mitigation potentials, adaptation potentials, and soil conservation. Descriptive statistics examined gender differences in farm and household decision-making. A multinomial logit regression model (MNL) was used to examine how gender-based household decision-making affects farmer enrollment in sustainable agrifood systems. MNL marginal effects coefficients were used to interpret the effects of independent variables on the sustainable agrifood systems enrollment, controlling for other factors and allowing comparisons across variables. The results of the study reveal that women play a significant role in the technical aspects of farming (64.4 %) and take most decisions regarding onfarm activities (70 %). However, decisions regarding farm earnings (81.4 %) and farm technology (84 %) are made by men. Household decision-making, particularly by women, significantly (P≤ 0.001) influences the adoption of different sustainable agrifood system packages. The use of practices with mitigation potential and soil conservation practices increased for households with decisions made by females, while the use of practices with adaptation potential decreased. The study emphasises the importance of extension services in encouraging farmers to use larger (more than 3 practices) sustainable agrifood system packages. Education and land ownership also positively (P≤ 0.05) influenced sustainable agrifood systems, particularly those with mitigation potential. Women have little decision-making power in agricultural production, according to decision-making results. Thus, gender-equitable agrifood systems adoption policies and programmes are needed to empower women. Such efforts can increase agricultural productivity, economic empowerment of women, gender equity, and social justice.

Keywords: Adoption, climate change mitigation, equity, gender, intrahousehold decision-making, sustainable agrifood systems

Contact Address: Mary Eyeniyeh Ngaiwi, The Alliance of Bioversity International and CIAT, Low Emission Food Systems, Calle 30 #15-04, 763537 Palmira, Colombia, e-mail: m.ngaiwi@cgiar.org

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Aiming for sustainability? An analysis of global commodity chains of gold mining and cattle ranching in Colombia

Barbara Schröter[1], Paula Andrea Sanchez-Garcia[1], Torsten Krause[2], Lasse Loft[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Germany*
[2]*Lund University Centre for Sustainability Studies (LUCSUS), Sweden*

The extraction of resources such as minerals, oil and agricultural products has serious social and environmental impacts. These include land grabbing, the displacement of small farmers and indigenous communities, deforestation, forest destruction and biodiversity loss. In recent years, consumers, governments and private companies have sought on responses to reduce the negative impacts associated with the production of mineral and agricultural commodities. Although rules and regulations on global commodity chains directly affect the actors involved in the chains these remain pretty abstract and unknown.

Therefore, in this article, we examine the gold and cattle commodity chains in Colombia. The aim is to identify the involved actors at different levels of governance (local, national, international) that have power and resources to shift to sustainable production. Based on Net-Map interviews, we map the value chain process together with the actors and discuss opportunities and barriers to improve the chains.

We show that the commodity chains of one and the same product are very different and extremely complex. In Colombia, there are different forms of mining and cattle ranching. In some of them, the shift towards sustainability is more advanced than in others, depending on the level of land use conflicts and the variety of actors involved. These different combinations of actors and conflicts lead to different social problems and levels of violence. Opportunities to improve commodity chains necessarily have to improve people's livelihoods and peacebuilding issues. We discuss these findings and their implications and limits for new regulations, for instance the new EU deforestation regulation.

Keywords: Actor mapping, cattle, global value chains, gold, informal institutions, Putumayo

Contact Address: Barbara Schröter, Leibniz Centre for Agric. Landscape Res. (ZALF), Eberswalder Str. 84, 15374 Muencheberg, Germany, e-mail: barbara.schroeter@zalf.de

Sustainable farm management practices for climate change mitigation and livelihood improvement

Amahnui George Amenchwi[1], Manga Veronica Ebot[2], Tening Aaron Suh[3]

[1]*International Center for Tropical Agriculture (CIAT), Climate Action, Colombia*
[2]*University of Buea, Fac. of Science, Dept. of Environmental Science, Cameroon*
[3]*University of Buea, Dept. of Agronomic and Applied Molecular Sciences, Cameroon*

Although soil microbial biomass (MBC) comprises less than 5 % of soil organic matter, it responds rapidly to changes in soil management practices and, therefore, is generally used as early indicators of changes in soil carbon. The objective of this study was to evaluate the effects of tillage practices (conventional tillage and no-tillage) and fertiliser types (synthetic, organic, and no fertiliser) on soil MBC. The field experiment, located in Bue, Southwest region of Cameroon. The experiment was carried out in a split-plot design with three replications with tillage systems as main plots and fertiliser types as sub-plots. Soil samples were collected at 0–15 cm depth at an interval of 4 (early season), 8 (mid-season) and 12 (late season) weeks during the 2020 and 2021 minor and major growing seasons respectively, for the determination of soil MBC by the chloroform fumigation and extraction method. The findings of the study showed that the main effect of tillage practice and fertiliser types was unsignificant ($p > 0.05$) in the 2020 and 2021 study season throughout the sampling period. Plots under zero tillage with control experiments (No.Till:CON) recorded the highest soil MBC in the 2020 season (201 kg^{-1} respectively) while in the 2021 season, plots under zero tillage with organic fertilisation (No.Till:ORG) recorded the highest (400.4 mg kg^{-1}) soil MBC. Soil MBC was higher in the 2021 season than in the 2020 season. These findings suggest that the use of compost in combination with either conventional tillage or no-tillage in farms in the study area could potentially enhance soil MBC.

Keywords: Carbon sequestration, climate change mitigation, fertiliser types, microbial biomass carbon, tillage practice

Contact Address: Amahnui George Amenchwi, International Center for Tropical Agriculture (CIAT), Climate Action, Km 17 Recta Cali-Palmira, 763537 Cali, Colombia, e-mail: g.amahnui@cgiar.org

Resilience to climate shocks among rural households in Nigeria

Oyebisi Olatunji Olajide, Adeola Olajide, Bolarin Omonona

University of Ibadan, Dept. of Agricultural Economics, Nigeria

Determining resilience to climate shocks could help to improve the livelihood of rural households, improve their farm production, and increase their ability to bounce back from the effects of climate change in a bid to contribute to economic growth and sustainable development. Therefore this study examines the climate change effects and the level of resilience of rural households to climate shocks in Nigeria. The study utilised Nigeria General Household Survey Panel Data (GHS-P) from the Living Standard Measurement Survey-Integrated Survey of Agriculture (LSMS-ISA) of 2010/2011 and 2018/2019 with a sample size of 2800 rural households. Descriptive statistics, ordered probit model, and Multiple Indicators Multiple Causes (MIMC) were used for data analysis.

The socioeconomic characteristics showed that there were more male-headed households than female counterparts with an average household size of 6. The mean age is 49 years which implies that the majority of household heads are still within the productive stage of their lives where 41 % have no formal education. The descriptive statistics revealed climate shocks affecting rural households in the study areas are 1.21 % destruction of harvest by fire, 5.32 % dwelling damaged/demolished, 25.21 % poor rain that caused harvest failure, 21.64 % flooding that caused harvest failure, 10.57 % pest invasion that caused harvest failure or storage loss, 6.50 % loss of property due to fire or flood, 2.18 % loss of land and 27.36 % death of livestock due to illness. The resilience index examined using MIMC model showed that 52.96 % were least resilient, 34.68 % less resilient and 12.36 % most resilient to climate shocks in the study areas. The results of the ordered probit show that education, dependency ratio, age, marital status, and social capital are significant variables that affect the level of resilience of rural households. Climate shocks demonstrate the urgent need for effective adaptation strategies to mitigate and manage the risks associated with climate change-induced shocks. Formal education should be more enhanced among rural households to strengthen their resilience capacity to overcome the negative impacts of climate change. It is also crucial to address climate challenges through policies and actions that prioritise resilience and sustainable development.

Keywords: Climate shocks, livelihoods, Nigeria, resilience, rural households

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Pollinating insect communities in livestock farming landscapes with silvopastoral systems in the Amazon region of Colombia

Karen Castaño Quintana[1], Julián Chará[2], Martin Dallimer[3], David Williams[3]

[1]*CIPAV, Conservation of Biodiversity, Colombia*

[2]*CIPAV, Sustainable Livestock Production, Colombia*

[3]*University of Leeds, School of Earth and Environment, United Kingdom*

Habitat loss is responsible for much of the global decline in biodiversity. Employing food systems that use sustainable practices in food production without endangering natural ecosystems is vital to halt biodiversity loss. Implementing silvopastoral systems in areas where livestock is already established could underpin improved food security, reduce land use change, minimize climate impacts, and contribute to biodiversity conservation. Here, we evaluate the role of two widely used silvopastoral systems - scattered trees in pasture and tree alleys - on pollinator diversity in the livestock-dominated Caquetá region of Colombia. We also evaluated forest patches and conventional livestock systems. We sampled pollinators with pan traps and entomological nets in four plots in 16 grids of 600 m x 600 m (a total sampling effort of 64 plots and 192 pan traps). We also evaluated vegetation composition and structure, and plant-insect interactions. We collected a total of 4,881 individuals of pollinating insects, comprising 600 morpho-species, 164 families, and 14 orders. The most abundant orders were Diptera (42.81 % of all individuals), Hymenoptera (29.96 %), and Lepidoptera (8.30 %). We found scattered trees in pasture sites had the highest abundance of pollinators. This system also hosted more complex plant/pollinator networks (links per species, diversity of interactions) in comparison with tree alleys and conventional livestock systems. Dominant and very dominant pollinator species (Hill's number = 2) predominated in conventional livestock systems while rare or scarce pollinating insects were dominant in scattered trees in pastures and forests. Our results highlight that silvopastoral systems can help to conserve Amazonian plant and insect pollinator communities. Indeed, scattered trees in pasture supported the highest richness and abundance of insects. However, conserving remaining forests are important for holding unique pollinating insect species and host the highest plant diversity.

Keywords: Colombian Amazon, conservation of biodiversity, livestock, pollinators

Nexus between climate change adaptation strategies and poverty: Evidence from rural farming households in Kwara State, Nigeria

Idowu Fasakin, Mobolaji Adejoorin, Fonsah Esendugue
University of Ibadan, Dept. of Agricultural Economics, Nigeria

Climate change has continuously threatened the sustainability of food production among rural farming households in sub-Saharan Africa, coupled with the increasing number of individuals living in outrageous poverty. Thus, this study empirically examined the relationship between climate change adaptation strategies and rural households' poverty in Kwara State, Nigeria.

Primary data collected with a well-structured questionnaire from six rural communities was used for the study while, descriptive statistics, Foster Greer and Thorbecke's (FGT) poverty measure, and logistic regression were used in data analysis. The study shows that there were more married males with an average household size of 7 members within the rural households. The majority of the farmers had no access to credit and were no longer in their productive years with ages between 61–80 years. Furthermore, more of them had only secondary education. The FGT analysis shows that the poverty line of the rural farming household was 1143.63, and a higher percentage of them were core-poor with only a minority who fell into the non-poor category. Sex, age, years of education, annual farm income, farming experience, access to agricultural information, and access to credit, being core and moderately poor influence the adoption of the five Climate Change Adaptation Strategies (CCAs) among the rural farming households as shown by the binary logistic regression analysis. We concluded that rural farming households were core poor and climate change adaptation strategies improved their well-being level. Therefore, the government and development partners in agriculture should focus on practical ways of disseminating better production systems and CCAs to rural farming households. Also, credit support facilities should be made available to the farmers across ages, and continuous education of the farmers on the appropriate CCAs that can be adopted in a particular locality should be encouraged.

Keywords: Adaptation strategies, climate change, poverty, rural farming households

Contact Address: Idowu Fasakin, University of Ibadan, Dept. of Agricultural Economics, Ibadan, Nigeria, e-mail: idowufasakin2010@gmail.com

Agricultural landscape and land use change

Online posters

Telecoupled urban demand drives agro-ecological land use in desert regions: New challenges for governing natural resources

Kira Fastner[1], Abdoul Kader Ibrahim Mohamed[2], Salouhou Djibrilla[3], Andreas Buerkert[1]

[1]*University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany*

[2]*University of Agadez, Fac. of Agronomy, Niger*

[3]*School Principal, Emalawlé, Niger*

A shift from subsistence-based to agricultural market production in remote oases at the southern fringe of the West African Sahara is particularly constrained by the availability of fertile land and quality irrigation water. While large demands of rapidly growing markets for specialty crops such as onion (*Allium cepa* L.) and potato (*Solanum tuberosum* L.) in West Africa's cities lead to a booming agricultural frontier in the South-Sahara, harsh environmental conditions in the Aïr Mountains of North-Niger determine the extent of land use for cash crop production and therefore income generation of the local population. Oasis agriculture may thus serve as an example for how farmers struggle for access to scarce common resources, whose overuse leads to a direct threat for the survival of a whole community, a phenomenon well known as the tragedy of the commons. Based on 70 year old colonial photographs, remote sensing analyses of satellite images, and field data collection between 2021 and 2023 in two small-scale oasis systems on Mont Bagzam and Timia, this study analyses (1) land use change in the oases between 1950 and 2023, (2) falling groundwater levels determined by topography and increasing water consumption for the production of cash crops, (3) the importance of communal management of natural resources, and (4) the potential of agroforestry and integrated crop-livestock management for sustainable intensified land use and new livelihood opportunities. Oasis systems on the mountain plateau of Mont Bagzam undergo highly dynamic changes towards irrigation-intensive cash crop production of onion, garlic (*A. sativum*), and potato leading to a five-fold increment in the cultivated land area between the 1950s until today, water shortages, and increasing abandonment of small-scale oasis gardens. Contrary, oasis gardens in the valley bottom of Timia, which have tripled in size over the past 70 years, constitute well managed agroforestry systems generating income from the sale of diverse crops such as wheat (*Triticum aestivum* L.), potato, citrus (*Citrus* L.), and pomegranate (*Punica granatum* L.) and serve as an example for sustainable and commonly governed agricultural production systems under difficult environmental conditions.

Keywords: Agro-pastoral systems, globalisation, land use change, natural resource management, rural-urban transformation

Contact Address: Kira Fastner, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: kira.fastner@uni-kassel.de

Assessment of intertemporal changes of land allocation to CSA practices and associated institutional framework in sub-Saharan Africa

Sarah Thione [1], Olivier Kashongwe[2], Dorothy Nampanzira[3], Gloria Nalule[3], Samson Katengeza[4]

[1]*Ministry of Agriculture Malawi, Planning, Malawi*
[2]*Leibniz-Institut für Agrartechnik und Biookonomie, Germany*
[3]*Makerere University, Livestock and Industrial Resources, Uganda*
[4]*Lilongwe University of Agriculture and Natural Resources (LUANAR), Malawi*

Compelling evidence in sub-Saharan Africa (SSA) shows that climate smart agriculture (CSA) has a positive impact on agricultural productivity. However, the uptake of CSA remains low, probably due to anthropogenic or human-related decisions but also to the countries' policy direction concerning CSA practices. This paper assesses the households' decisions to allocate agricultural land to CSA technologies in spatial and temporal scales, as well as the institutional and policy strategies susceptible to promote the scaling of CSA practices among households. We use the state-contingent theory and mixed methods to analyse various primary and secondary data sources from Kenya, Malawi and Uganda. The results show that household decision to use CSA and the extent of agricultural land allocation to CSA remains low, with a negative trend over time in SSA. While agricultural land is increasing, forestland is decreasing across the target countries. Since the year 2000, the area under irrigation has doubled in Malawi and increased by 50 % in Kenya, while little change was observed in Uganda. Owned land and access to land through rental markets were positively associated with land allocation to CSA technologies, particularly where land pressure is high. This was the case for Malawi, where 46.3 % of land was allocated to CSA practices over the last 5 years, contrasting with the 10.3 % over the same period in Uganda. Soil control measures, use of organic manure and irrigation were common CSA practices between Kenya, Malawi and Uganda. Results also show that households experiencing rainfall shocks in a crop dominated production system, such as in Malawi, significantly ($p < 0.05$) allocate more land to CSA practices the following year without increasing the extent of land allocation to CSA. The policy assessment at country level suggests that adaptation (54 %) is the focus of CSA strategies in SSA countries (67 % for Kenya, 50 % for Malawi and Uganda). Therefore, scaling up CSA in SSA will require that agricultural-related policies to focus on access to land and the associated effects on application of CSA practices at the household level across space and over time.

Keywords: Agricultural policy, climate change adaptation, Kenya, land allocation, Malawi, Uganda

Contact Address: Olivier Kashongwe, Leibniz-Institut für Agrartechnik und Biookonomie, Max-Eyth-Allee 100, 14469 Potsdam, Germany, e-mail: okashongwe@atb-potsdam.de

Mapping heterogeneous smallholder maize-cassava systems in southwest Nigeria based on Sentinel–1 and Sentinel–2 time series

FELICIA O. AKINYEMI[1], PHILIPPE RUFIN[2], ESTHER S. IBRAHIM[3], PATRICK HOSTERT[4], LUCIA O OGUNSUMI[5], OLUGBENGA A. EGBETOKUN[5], CHINWE IFEJIKA SPERANZA[1]

[1]*University of Bern, Inst. of Geography - Land Systems and Sustainable Land Management, Switzerland*
[2]*UCLouvain, Earth and Life Institute, Belgium*
[3]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*
[4]*Humboldt-Universität zu Berlin, Geography Department, Germany*
[5]*Obafemi Awolowo University, Inst. of Agricultural Research and Training, Nigeria*

Earth observation is key for agricultural monitoring across large regions. Operational agricultural monitoring schemes involve the mapping of agricultural inputs, land management and/or crop types. Approaches developed in consolidated agricultural systems in Europe or the United States, have limited applicability in more heterogeneous systems. An example is crop type mapping which is challenged by the presence of inter-cropping, i.e., the simultaneous presence of multiple crops on a field, due to the high intra-field variability in crop types, growth stages and non-crop vegetation. Consequently, regional-scale crop type mapping approaches in smallholder agriculture mostly focus on specific crops and do not account for crop mixtures or double growing cycles. A combination of Sentinel-1 radar and multispectral Sentinel-2 time series was used to separate mono-cropping from mixed-cropping in heterogeneous maize-cassava farming systems across the lower Guinea Savannah of southwest Nigeria. The region is characterised by high cloud cover during much of the growing season that affects non-cloud-penetrating Sentinel-2 optical data, while it provides much richer spectral information than Sentinel-1 radar data. Field data for the growing season 2022/2023 comprise 1,150 samples. Eight classes were defined indicating crop types, mixtures, and growing periods (early maize, late maize, early cassava, late cassava, maize-cassava, yam, rice, and other crops). Gap-free spectral-temporal features at bi-weekly, monthly, and bi-monthly intervals for the growing season (Sentinel-1) and the off-season (Sentinel-2) were pro-cessed in Google Earth Engine. Random Forest models were trained to conduct experiments assessing the suitability of the two sensors and the three temporal intervals. Results were validated using k-fold cross-validation. The best model combining Sentinel-1 and Sentinel-2 at monthly intervals yielded a mean overall accuracy of 0.78

Contact Address: Felicia O. Akinyemi, University of Bern, Inst. of Geography - Land Systems and Sustainable Land Management, Hallerstrasse 12, 3012 Bern, Switzerland, e-mail: felicia.akinyemi@gmail.com

(+/-0.08 %) and median User´s and Producer´s accuracies above 0.60 for all classes. Models using only radar data underperformed with mean overall accuracies below 0.50 and models using only multispectral data had comparable overall accuracies but lower class accuracies for the mixed classes. Our approach demonstrates the potential of integrating radar and optical time series in cloud-prone regions with complex agricultural and forest mosaic landscapes involving mixed crops and thereby provides valuable information for downstream assessments of crop production and yields.

Keywords: Crop mixtures, crop type mapping, maize-cassava

Novel metrics to describe deforestation dynamics in global commodity frontiers

Matthias Baumann, Ana Buchadas, Tobias Kuemmerle

Humboldt-Universität zu Berlin, Geography Department, Germany

Tropical deforestation is a major contributor to climate change and results in the widespread degradation of ecosystem services, important for local communities. A major cause of deforestation in the tropics is the expansion of various forms of agriculture by diverse actors, resulting in highly heterogeneous and complex deforestation frontiers. Better understanding and characterising these frontiers remains a major challenge for sustainability science. Here, we present a novel way to describe frontier processes in deforestation frontiers, and we showcase this for the South American Gran Chaco, a global deforestation hotspot. Using satellite-based land cover time series and decision trees we develop frontier metrics describing different dimensions of frontier processes, including baseline forest, speed of deforestation, level of activeness of deforestation, and the post-deforestation land-cover trajectory. Our results show that more than 19.3 million ha of woodlands were converted to agriculture 1985–2020, with clear distinctions of the proximate causes between the 1980s and 1990s when ranching expansion drove deforestation, and a period during the mid-2000s when cropland expansion was dominant. In addition, we found that direct conversions to croplands occurred in form of rapidly progressing frontiers, but the Chaco also contains many areas where slowly progressing frontiers dominate and where forests were initially cleared for ranching before eventually being converted to cropping, highlighting the need for considering post-deforestation land uses for better linking frontier dynamics to the underlying processes. Our concept of frontier metrics provides a robust and transferable way to move away from describing time series of land cover towards a deep process-understanding of processes in commodity frontiers in the world's tropical dry forests. Our approach can identify high-level, recurring frontier types and can therefore be a step towards more context-specific monitoring and policy responses to deforestation.

Keywords: Chaco, commondity frontiers, deforestation, South America

Application of the DPSIR framework for the identification of land use and land cover change drivers from forest to agriculture in the dry woodlands of Northwestern Ethiopia

Asabeneh Alemayehu Munuyee, Alemtsehay Eyassu, Alemayehu Negassa, Mulat Shebabaw

Ethiopian Forestry Development (EFD), *Ethiopia*

The drivers, pressure, state, impact, and response model was used in the dry woodlands of Burie and Jawi districts, Ethiopia, to assess the drivers, impacts, and potential solutions of land use and land cover shifts from forest to agricultural. Two villages, Sewatam and Kaba Abo in Jawi, and Gedam Lijamor and Fetam Seltom in Burie, were chosen for their potential for land conversion from forest to agriculture. Data was gathered through 343 household surveys, two focus group discussions, five key informant interviews, field observations, and literature reviews. In all areas, the primary drivers of land use conversion from forest to agricultural were firewood gathering, small-scale agriculture, and charcoal production. At Burie, population dynamics, settlement, and increased agricultural demand are the key indirect drivers of change, whereas at Jawi, livestock pressure or overgrazing and a lack of forest law enforcement are the top three indirect drivers of change. The pressures of land use and land cover changes for Burie are high demand for agricultural land (91.8 %), overcrowding of communal land (86.2 %), and overgrazing of land (81.0 %), whereas for Jawi, the main pressures are high demand for agricultural land (97.3 %), completion of communal land (93.9 %), and increased demand for forest products (87.2 %). All of these drivers and pressures contribute to land degradation, forest conversion, soil fertility loss, poverty, high floods and droughts, poor water quality and availability, a scarcity of wood for construction and fuel, as well as rural-to-urban migration. Local communities, governments, and non-governmental organisations responded to the effects by diversifying their livelihoods and raising awareness. The use of policies and laws to manage impacts was determined to be inadequate. Land use and land cover changes in the study areas were demonstrated to have a major impact on biodiversity, land, water, and community livelihoods. The drivers and impacts could get worse as a result of the observed increase in climate change and population growth if responses are not made accordingly. As a result, it is important to expand interventions such as resource conservation, livelihood diversification, agricultural intensification, awareness creation, land use policy consideration, and law enforcement

Keywords: DPSIR, drivers, Ethiopia, land use land cover

Contact Address: Asabeneh Alemayehu Munuyee, Ethiopian Forestry Development, Bahir Dar Center, Policy and Socioeconomics, Addis Alem, 2128 Bahir Dar, Ethiopia, e-mail: alemayehuasabeneh@yahoo.com

ID 686

How to increase the benefits of soil carbon projects for smallholder farmers? A case study from Kenya

Fiona Hasenbach, Athena Birkenberg, Christine Bosch, Manuel Díaz, Regina Birner

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Future and current agricultural activities rely heavily on the fertility of soils. Implementing Sustainable Agricultural Land Management (SALM) practices as promoted in soil carbon sequestration projects target the increase of soil organic carbon (SOC) stocks in agricultural soils. Due to the wide-ranging positive effects of increasing carbon contents in soils, soil carbon sequestration projects have been the focus of development initiatives in the recent decade to supply carbon credits. Such projects have complex organisational structures, long durations (20 years) and multiple actors involved, ranging from farmers to project implementers and carbon buyers. Smallholder farmers who implement SALM practices for the issuance of carbon certificates make up the majority of project participants. However, they are largely underrepresented in project design, monitoring and evaluation, and benefits for smallholder farmers are rather limited and active participation is low. The long-term motivation and involvement of smallholder farmers implementing SALM practices which are crucial for the legitimacy of the carbon credits issued, has received minimal attention in research. This study investigates the potential of farmer participation in data collection for monitoring of soil carbon projects and how the related benefits can be increased for participating smallholder farmers. The case study employs the process net-map method, qualitative interviews, focus group discussions, and the cellphilm and photovoice technique, to get deeper insights into an ongoing soil carbon project, the Western Kenya Carbon Project. Two strategies for increasing benefits have been identified: a) Participatory monitoring involving farmers in data collection and monitoring for soil carbon projects. This ensures the required data collection for monitoring purposes and may contribute to a deeper understanding and ownership of the carbon project by participating farmers. b) Sharing collected data with farmers to provide feedback on their farming performance. This can be achieved by project implementers using the data as a basis for tailor-made capacity building and customized extension and advisory services. The results could help policymakers, donors and project implementers to design more inclusive monitoring systems for soil carbon projects.

Keywords: Capacity building, development projects, participatory monitoring, soil carbon project

Agro-ecological effects of terrestrial sand mining in Accra metropolitan area, Ghana

Katharina Hemmler, Andreas Buerkert

University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

Sand, being the main component of concrete, constitutes the skeleton of every city in our modern civilisation. Even though sand is a non-renewable resource in human timescales, it is mined globally at exorbitant scales from rivers, marine and terrestrial deposits, constituting the second most consumed natural resource after water. Increasingly, sand and its extraction draw media and scientific attention. But while global research focusses on open pit and river sand mining in Asia and the Global North, data on terrestrial sand mining in sub-Sahara Africa (SSA) are very limited. Ghana, like elsewhere in the region, is experiencing a high rate of development related urbanisation, leading to resource extraction far beyond its natural replenishing rate by weathering and natural erosion / deposition. This study focuses on Accra, Ghana's political, economic and cultural capital where sand mining, or locally called "sand winning", is most predominant. The source of sand is farmlands in the peri-urban and rural areas reaching up to 60 km from the city centre leading to social and environmental problems such as land degradation, loss of farmlands, and food and water insecurity. Since Accra also depends on the surrounding rural areas for food production, sand mining and agriculture are rivals in the competition for land. This study comprises qualitative and quantitative interviews as well as soil analysis to (i) determine the effects of sand mining on agricultural productivity and farming incomes, (ii) assess the effect of sand mining on soil fertility through a comparison of physical, chemical, and biological parameters of mined and unmined fields, and (iii) determine positive and negative effects of sand mining on the livelihoods of mining communities.

Keywords: Environmental impacts, illegal, natural resource extraction, urbanisation, West-Africa

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Contact Address: Katharina Hemmler, University of Kassel, Organic Plant Production and Agroecosystem Research in the Tropics and Subtropics, Steinstraße 19, 37213 Witzenhausen, Germany, e-mail: Katharina.Hemmler@uni-kassel.de

ID 557

Factors affecting the transition to the long-rotation plantations of smallholders. A case study in Quang Tri province, Central Vietnam

Hien Vo Thi Hai, La Thi Tham, Han Doan Thi

Vietnam National University of Forestry, Vietnam

In Vietnam, plantation forests serve as an important source to sustain the material supply for the wood-based sector, especially after the restriction of timber harvests from natural forests in 2014. Approximately half of the plantation forest area is currently under the management of smallholder households. Of the cultivated species, the *Acacia* hybrid (*Acacia auriculiformis* × *Acacia mangium*) is one of the most important due to its suitability for local conditions, early benefits and low upfront investment. The *Acacia* hybrid plantations contribute to smallholders' diversification strategy which enables them to reduce farm risk, increase income, and enhance food security. Long-rotation plantations, additionally, are anticipated as a potential manner to mitigate climate change impacts. Despite that, the management practice of small-scale timber producers is usually at a low level with the prevalence of premature harvest. A comprehensive analysis of this sector, so far, is lacking. This paper elucidates the key factors affecting the transition from the common premature harvest to the long-rotation plantation of small-scale timber producers in Quang Tri province where the species has been cultivated for approximately 30 years. 315 household heads were interviewed, following a stratified random sampling approach. Binary logistic regression and Bayesian network models were used for data analysis. The findings were validated in group discussions and expert interviews.

The results demonstrated the key determinants of smallholder households for long-rotation plantation adoption including (i) the availability of capital for investment; (ii) participation in FSC projects; (iii) assurance of seedling sources; (iv) understanding on large-sized timber market; and (v) community support. Recommendations promoting small-scale timber producers toward a more sustainable timber management practice, including long-rotation plantation as well as the role of the government, supporting organisations and industry sectors in achieving these targets were delineated.

Keywords: Adoption, central Vietnam, long-rotation plantation, smallholder households, sustainable development

Contact Address: La Thi Tham, Vietnam National University of Forestry, Xuan Mai Town Chuong My District, Hanoi, Vietnam, e-mail: latham.hvtc@gmail.com

The best practices of royal project model on reducing hot spots and pm 2.5 in northern Thailand

Olaya Shewchenko, Jarunee Pilumwong, Kamontip Raorat, Adirek Punyalue

Highland Research and Development Institute (Public Organization) HRDI, Research, Thailand

Thailand Royal Project's record clearly demonstrates that it was able to change the highland communities from destitute and narcotic crops-dependent to narcotic crops-free, self-reliant ones, even contributing to the countries overall security and sustainability. As the successful of Royal Project Foundation development model (RPF model) with adapted to be used for the development of other highland areas for increase income and reduce smog from conventional agriculture. Smog and PM 2.5 are main problems of northern Thailand, caused from burning residue in agricultural areas. The objectives were study the implementation of the best practices of the Royal Project model to reduce smog or hot-spot area and determined key factor of farmer change from conventional to best practices agricultural systems, Data were collected 95 % (66 samples) duration between 2020 to 2023 at Pang Dang Nai village, Chiang Dao district, Chiang Mai, Thailand. The study were collected at Pang Dang Nai village (Pa Laung minority group), 307 population and 64 household, with altitude between 600–700 m (MSL). The conventional agricultures are field crops consist of maize, rice bean and cowpea. There were operated land preparation by burning crop residue. The study found that four types of agricultural systems while, field crop – fruit tree – green house – livestock systems show highest income by 24,612 \$/ha/year and less income in monoculture by 12,718 \$/ha/year. The hot –spot in the decreased by 91.3 in 2022 comparing to 2020. The key factors of changing were, 1) the promoting of the new agricultural system from official staff such as supporting production factors, providing training program, and promoting new management knowledge 2) Quantity and quality of products. The results concludes that the RPF model can be extended and further developed in other areas, which will lead to sustainable development under the preservation of natural resources and the environment, as well as solving the problem of smog in the area for sustainable agriculture on highland.

Keywords: Agricultural system, and smog, best practices in the Royal Project, highland

Contact Address: Olaya Shewchenko, Highland Research and Development Institute (Public Organization) HRDI, Research, 65 Moo 1 Suthep, 50200 Chiang Mai, Thailand, e-mail: olayaamam@gmail.com

Mapping crop types and cropping systems in Nigeria with sentinel-2 imagery

Esther S. Ibrahim[1], Philippe Rufin[2], Leon Nill[1], Bahareh Kamali[3], Claas Nendel[1], Patrick Hostert[1]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*
[2]*Humboldt-Universität zu Berlin, Geography Department, Germany*
[3]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany*

Reliable crop-type maps from satellite data are an essential prerequisite for quantifying crop growth, health, and yields. However, such maps do not exist for most parts of Africa, where smallholder farming dominates. Prevalent cloud cover, small farm sizes, and mixed cropping systems pose substantial challenges when creating crop-type maps for sub-Saharan Africa (SSA). There is accordingly the need to explore remote sensing data more rigorously and to develop methodologies for detecting and mapping crops. We here suggest a mapping scheme based on freely available Sentinel-2 A/B (S2) time series and very high-resolution SkySat data to map the main crops, maize and potato, and intercropping systems including these two crops for the main crop production region of Nigeria, Jos Plateau. We analysed the spectral-temporal behaviour of mixed crop classes to improve our understanding of inter-class spectral mixing. Building on the Framework for Operational Radiometric Correction for Environmental Monitoring (FORCE), we preprocessed S2 time series and derived spectral-temporal metrics (STM) from S2 spectral bands for the main temporal cropping windows. These STMs were used as input features in a hierarchical random forest classification. Our crop type mapping resulted in the first wall-to-wall crop type map for this key agricultural region of Nigeria and achieved an overall accuracy of 84 % for crop/non-crop discrimination, and 72 % for the five most relevant crop classes. Maize is the dominant crop, followed by mixed cropping systems, including maize–cereals and potato–maize cropping; potato was found to be the least prevalent class. About 48 % of the mapped classes of interest are intercropped, further revealing the implication of intercropping in smallholder regions. Plot analyses based on a sample of 1,166 individual fields revealed largely homogeneous mapping patterns, demonstrating the effectiveness of our classification system also for intercropped classes, which are temporally and spatially heterogeneous. Moreover, we found that small field sizes (75 % of fields smaller than 1 ha) were dominant in all crop types, regardless of whether or not intercropping was used. Our study offers guidance for creating crop-type maps for smallholder-dominated systems where intercropping is prominent, which are previously lacking. Mapping intercropped classes will provide better yield estimates for smallholder regions.

Keywords: Spectral-temporal metrics, classification, intercropping, maize, potato, random forest, SkySat, smallholder agriculture, sub-Saharan Africa, time series

User-centred agricultural drought monitoring: Integrating multisource remote sensing data for effective decision making

S. Mohammad Mirmazloumi[1], Harison Kipkulei[1], Maximilian Schwarz[2], Jonas Franke[2], Tobias Landmann[3], Rose Waswa[4], Tom Dienya[5], Gohar Ghazaryan[1]

[1]*Leibniz Centre for Agricultural Landscape Research (ZALF), Germany*
[2]*Remote Sensing Solutions (RSS) GmbH, Germany*
[3]*International Centre of Insect Physiology and Ecology (icipe), Kenya*
[4]*Regional Centre for Mapping of Resources for Development, Kenya*
[5]*Ministry of Agriculture and Livestock Development, Kenya*

Monitoring agricultural systems is essential for ensuring sustainability and achieving sustainable development goals. Achieving this requires understanding how climate extremes and field management practices impact crop yields in a spatio temporal explicit and scalable way. To address this challenge, we propose an approach that leverages the increasing availability of freely accessible earth observation (EO) data to monitor changes in abiotic stressors in croplands accurately and frequently by tracking subtle changes in time series. Our approach focuses on developing cloud-based processing algorithms that enable the accurate and spatially explicit analysis of drought hazards and impacts using remotely sensed images. For this, several datasets including time series from 20-meter Sentinel-2 optical images, and 10-meter Sentinel-1 radar data are used for the national scale analysis in Kenya, where exceptional multi-season droughts were observed in recent years. In addition, drought-relevant agricultural information is derived, such as high-resolution crop management data, including irrigation at a national level and localised information on cropping practices in pilot areas. Our approach emphasises user engagement by actively engaging stakeholders to identify needs and incorporate their perspectives into the data development and validation process to ensure that the data is tailored to end users needs.

Our innovative approach to drought monitoring using EO data and agricultural information development enables more precise monitoring of drought conditions and crop status, facilitating better decision-making and targeted interventions in drought affected areas. By providing relevant and up-to-date information to stakeholders and policymakers, our approach can aid in developing effective drought management strategies and policies.

Keywords: Cloud computing, drought, earth observation, Kenya, Sentinel

Contact Address: S. Mohammad Mirmazloumi, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalderstraße 84, 15374 Müncheberg, Germany, e-mail: sm.mirmazloumi@zalf.de

ID 590

Transfer learning for smallholder field delineation and field size estimation in sub-Saharan Africa

Philippe Rufin, Patrick Meyfroidt

UCLouvain, Earth and Life Institute, Belgium

Agricultural monitoring based on Earth observation is challenging in tropical smallholder landscapes, due to the spatially fragmented and dynamic nature of the agricultural systems leading to region-specific and diverse portfolios in terms of crops, productivity, and land management. These complexities are particularly prevalent in sub-Saharan Africa (SSA), where a large fraction of the agricultural land is managed by semi-subsistence smallholder farmers, which operate under constrained access to capital and inputs. As a consequence, the spatial distribution of agricultural fields, field sizes, crop types, and productivity remains an empirical blind spot for most parts of SSA. In this study, we combine state-of-the-art deep learning models with very-high spatial resolution satellite imagery to produce accurate delineations of individual smallholder fields. We make use of transfer learning by fine-tuning deep learning models trained in France and India for use in northern Mozambique and southwest Nigeria. We experiment with different strategies for fine-tuning models across regions based on human-annotated training data and investigate options for self-supervision to facilitate model transfer while reducing reference data requirements. We test the performance of pre-trained and fine-tuned models for object-level field delineation and site-level field size estimation based on the median intersection over union (mIoU) and mean site-level RMSE (mRMSE), respectively using independent reference data.

Our results indicate i) good performance of the pre-trained model in both field delineation (mIoU: 0.699) and field size estimation (mRMSE: 0.071 ha), ii) consistent performance improvements for all fine-tuning experiments compared to the pre-trained model (mIoU increases: 0.045–0.058, mRMSE decreases: 0.008 ha–0.031 ha), revealing substantial improvements achieved by regional fine-tuning, and iii) comparable performance increases for supervised and self-supervised approaches, with low differences in object-level (ΔmIoU: 0.014), and site-level performance scores (ΔmRMSE 0.017), indicating a great potential for self-supervised transfer learning in reducing reference data requirements. This study presents a stepping stone for overcoming the persisting data gaps in smallholder agriculture of SSA by producing detailed field delineations at scale, which support field-level crop type and yield estimation, and allow for field size estimation in smallholder regions.

Keywords: Deep learning, geospatial, land management, machine learning

Intrinsic drivers of land abandonment in Africa: A case study of Nigeria

Oluwaseyi Olasoji, Miroslava Bavorová

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

Land abandonment is a burgeoning global phenomenon, with increasing interest not only in its causes, but also in its implications for global food security, the environment, and ecosystems. Much research, particularly in Europe, Asia, and North America, has focused on and highlighted the broad extrinsic drivers of land abandonment. However, there is limited research on this topic in Africa and much less on the intrinsic drivers of land abandonment globally. This study examines both the extrinsic and intrinsic drivers of land abandonment in Africa, using Nigeria as a case study, focusing on the behavioral aspects and how they influence the decision to abandon agricultural land. Therefore, this research examines the role of place attachment in the decision to abandon land. A multi-stage sampling design was used for this study. The first stage involves randomly selecting 3 out of the 6 geopolitical zones in Nigeria; the second stage involves randomly selecting 1 state from each of the selected geopolitical zones. The third stage involves the purposive selection of 3 rural or peri-urban areas from the respective local governments of the selected states, comprising 16 local governments. The fourth stage randomly selects 50 farmers in each of the selected local governments, totaling 450 respondents. Data were collected using a semi-structured questionnaire and analysed using binary logistic regression models. Focus group discussions and key informant interviews also provided further insights and qualitative data on the behavioural aspects influencing land abandonment. Temporary land abandonment was prevalent in the study areas, characterised by the cessation of agricultural activities on the land for some time to allow the land to rest or regain lost nutrients. Preliminary findings from the data analysed show that both extrinsic variables (age, level of education, farm income, number of crops grown, livestock, problems with flooding, access to subsidies, practice of mechanised farming) and intrinsic variables (respondents being born in the community, respondents' willingness to sell their land, problematic experience of hiring labour and level of satisfaction with farming experience) have a significant impact on the likelihood of abandoning their agricultural land.

Keywords: Africa, behavioural, land abandonment, Nigeria, place attachment

Contact Address: Oluwaseyi Olasoji, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Prague-Suchdol, Czech Republic, e-mail: olasoji@ftz.czu.cz

ID 637

Combining crop-cuts with remotely-sensed weather data to predict maize yields in sub-Saharan Africa

Max Hofmann[1,2], Lena Büschel[2,1], Florian Schierhorn[1], Christopher Krause[1,2], Daniel Müller[3,1]

[1]*IAMO - Leibniz Institute of Agricultural Development in Transition Economies, Structural Change, Germany*
[2]*Martin Luther University Halle-Wittenberg, Germany*
[3]*Humboldt-Universität zu Berlin, Integrative Research Institute on Transformations of Human-Environment Systems (IRI THESys), Germany*

Weather extremes increasingly threaten agriculture and food security, particularly in the Global South. In sub-Saharan Africa, where agriculture is dominated by smallholder farming, extreme events such as droughts and heavy rainfall frequently lead to production shortfalls that jeopardise local livelihoods. We evaluated how weather patterns determine yield variability using 20,660 maize yield measurements recorded between 2016 and 2020 from six countries (Kenya, Tanzania, Rwanda, Malawi, Zambia, Burundi). These so-called crop-cuts are considered the gold standard for yield estimation because they reflect actual plot-level harvests that are weighed and recorded according to standardised protocols. We used the dates for seeding and harvest of each crop-cut to specify the length of the growing season and calculated extreme weather indices for each crop-cut-specific growing season from freely available remote sensing products, including drought, heat, heavy precipitation, and evaporative stress. We used random forests, a machine learning algorithm that can handle collinearity among predictor variables and nonlinear relationships with the response variable, to quantify the contribution of weather to maize yields. Depending on the country, our out-of-sample predictions reach R^2-values of between 0.14 and 0.42, suggesting that weather explains up to almost half of the observed yield variability in some regions. This study advances the insights into assessing the effects of extreme weather on smallholder yields with machine learning. Our results can inform the development of tailored adaptation measures such as local index insurance products and ultimately contribute to improving regional food security in light of accelerating climate change and increasing risk for future extreme weather events.

Keywords: Climate change, crop-cuts, extreme weather, machine learning, yield prediction

Owning the land, but at what cost? Changes in power relations and land accumulation in cattle ranching in wartime Colombia, 2001–2012

Natalia Triana-Angel[1], Daniela Mejía Tejada[2], John Jairo Junca Paredes[1], Stefan Burkart[1]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*
[2]*Independent researcher, Colombia*

Given the length of the conflict and multiplicity of actors embedded in the Colombian war, it becomes necessary to understand the impact that violence, displacement and dispossession have amongst rural producers and in the agroeconomic sector in general. The struggle for land tenure, the management of natural resources, and the economic and social centrality of cattle ranching for various armed actors, are therefore vital aspects to consider in understanding the effects of the conflict in rural Colombia. Important contributions have been made, shedding light on the nature of war in Colombia and its negative societal effects, as well as a vast theoretical corpus has been established on the importance of livestock, not only for producing families, but also for rural elites and other active agents of armed confrontation. However, in addition to the already known effects, both of war (such as dispossession, displacement, loss of social order, poverty, etc.), and the role of livestock in it (as a means of financing confrontation, among others), the information available in Colombia suggests that other important and unexpected changes take place in land tenure, especially for women farmers. This research thus delves into the transformations in the ownership of agricultural production units (UPA) dedicated to livestock production during the escalation of conflict in Colombia (2001–2012), to understand the relationship between war and societal dynamics of land tenure through a quantitative approach. Available data indicates that dynamics such as displacement, increasing violence rates and territorial instability contribute, at least to a certain extent, to transforming family dynamics and patterns in land tenure and administration. This is relevant not only for understanding the complexity of women's roles and functions within livestock farming, and for the analysis of their contingent agency in war contexts, but also contributes to a larger narrative on the unexpected outcomes of a longstanding war. Here we revisit the narratives about the role and participation of women in conflict and in livestock farming, while also exploring the circumstances in which gender roles, family relations and land ownership can shift.

Keywords: Armed conflict, cattle expansion, gender roles, land tenure, panel data

Contact Address: Natalia Triana-Angel, The Alliance of Bioversity International and CIAT, Trop. Forages Program, Cali, Colombia, e-mail: n.triana@cgiar.org

Effect of climate and land-use change on the structure and diversity of woody vegetation – lessons from West Africa's woodlands

Maximus Anochirim[1], James Nana Ofori[2], Amanuel Gebremichael[2], Anja Linstädter[2]

[1]University of Greifswald, Inst. of Botany and Landscape Ecology, Germany
[2]University of Potsdam, Inst. of Biochemistry and Biology, Germany

In this scientific article, we investigated the effect of climate and land-use change on the structure and diversity of woody vegetation in West Africa's woodlands, drawing important lessons from empirical studies and research findings. Land-use change in terrestrial ecosystems plays a vital role in many global change processes and consequently, has a significant effect on biodiversity and ecosystems. In addition to changes in how land is being used, human-induced climate change in the last century has exacerbated the impact of these pressures. We examined the complex interactions between climate change, land-use change, and woody vegetation dynamics, by asking the following research questions: i. Are effects similar or do they differ across different land-use types? ii. Are effects similar or do they differ across different climatic zones?

Sampling was done from March to June 2022 (3 months) in random plots established in Forests, Fallows, and Croplands (representing different gradients of anthropogenic changes in Land-use) and in two major ecological zones of Ghana: Moist Semi-deciduous and Dry Guinea Savannah zones (representing a steep climatic gradient). We established a total of 60 plots, with each plot measuring 50 × 50 sq. m, and collected data on all woody species found within them (dbh, height, taxonomic identification, and other parameters to measure their functional traits). We used size-class distributions (SCDs) and a range of diversity measures to analyse the structural composition, taxonomic and functional diversity of each land-use type.

Our synthesis of current knowledge provides important insights for policymakers, conservation practitioners, and field researchers working on ecological and environmental challenges. Furthermore, it contributes to our understanding of how these ecosystems may respond to future environmental changes and inform strategies for their sustainable management and conservation

Keywords: Climate change, land-use change, West Africa, woody vegetation

Visible and near-infrared spectroscopy for agricultural soil analysis using alternative data preprocessing and wavelength selection

Natchanon Santasup[1], Parichat Theanjumpol[2], Nuttapon Khongdee[3]

[1]Chiang Mai University, Dept. of Plant and Soil Sciences, Fac. of Agriculture, Thailand
[2]Chiang Mai University, Postharvest Technology Research Center, Thailand
[3]Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand

Visible and near-infrared (VIS/NIR) spectroscopy has been widely utilised to predict soil properties due to its rapidity, affordability, and environmental friendliness. However, the accuracy of predictions varied due to the regions, soil pedological characteristics, and particularly site-specific practices. Therefore, soil-specific predictive models should be developed to increase the accuracy of the model. This study aimed to evaluate the effect of data preprocessing and wavelength selection on the prediction of organic matter (OM), total carbon (TC), and total nitrogen (TN) in agricultural soil using NIRs. A total of 148 soil samples were randomly collected from different agricultural areas in northern Thailand for soil chemical components i.e. OM, TC, and TN analysis. The Walkley-Black method was used to analyse OM, while TC, and TN were analysed by dry combustion technique. Soil samples were then scanned for VIS-NIR (400–2500 nm of wavelength), NIR (700–2500 nm of wavelength), and long-wave near-infrared (LWNIR) (1100–2500 nm of wavelength). Five data preprocessing techniques were tested, including smoothing (SMO), Saviizki-Golay derivatives (SGD), multiplicative scatter correction (MSC), mean centering (MC), and standard normal variate (SNV). Data preprocessing techniques were combined with partial least squares regression (PLSR) and principal component regression (PCR). The performance of the prediction was evaluated by the coefficient of determination (R^2) and the root mean square (RMSE). For a result, the best prediction was obtained with the combination of SMO preprocessing and the PLSR model in 400–2500 nm of wavelength. The R^2P values of OM, TC, and TN were 0.83, 0.81, and 0.84 and RMSEp were 0.76, 0.47, and 0.04, respectively. This study demonstrated that the model could be used as an alternative method for determining OM, TC and TN in agricultural soil. However, large-sample populations and improved model algorithms could further improve prediction.

Keywords: Chemometrics, model, prediction, soil property

Leveraging earth observation and crop modelling for crop condition monitoring and production assessment in Busia County, Kenya

Harison Kipkulei[1], Francis Oloo[2], Pamela Ochungo[2], Stefan Sieber[1], Hussein Farah[2], Gohar Ghazaryan[1]

[1]*Leibniz Centre for Agricultural Landscape Research (ZALF), Germany*

[2]*The Technical University of Kenya (TUK), School of Surveying and Spatial Science, Kenya*

Understanding the dynamics of agricultural productivity in highly heterogeneous smallholder landscapes is critical for improving food and livelihood security. This study presents an integration of crop modelling and remote sensing approaches to improve the understanding of crop conditions and assess the productivity of dominant crops in Busia County in Kenya. Effectively, crop modelling and remote sensing analysis using multi-source and freely available earth observation data are proposed to classify the cropping systems in the region, predict yield, and assess the influence of climatic stressors on crop production. The first step applies synthetic aperture radar data from Sentinel-1 and optical imagery from Sentinel-2 to map crop types in the study area. The classification is based on the existing crop type information from different sources, which is harmonised for the study area and is used for pixel-level classification using the random forest machine learning model for the years where the reference data is available. The trained model is later used for the same years when the training data is available and the following year for an early-season crop map. These maps, along with meteorological forecasts, existing drought risk, and yield information, are used to derive essential agro-climatic indicators. The output from the classification process is further integrated into the simulation of maize production and assessment of yield anomaly in the study area for a seven-year period in which observed yield is available. For this, a parameterised and evaluated DSSAT-CERES-Maize model is proposed to predict yields and assess yield anomalies at fine spatial and temporal scales. The simulated dynamics of production across the study region are useful for enhancing agronomic decisions and driving food security planning in the region. The study highlights the value of integrating earth observation data and crop modelling to enhance the understanding of smallholder agricultural productivity. The proposed approach is scalable to other regions and relies on freely available data. Thus, it could improve the monitoring of crop conditions and productivity in data-scarce landscapes.

Keywords: Climatic stressors, crop conditions, phenology, remote sensing

Contact Address: Harison Kipkulei, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalderstraße 84, 15374 Müncheberg, Germany, e-mail: harison.kipkulei@zalf.de

Rural-urban transformation determines cropping patterns in Morocco's mountain oases

Youness Boubou, Kira Fastner, Thanh Thi Nguyen, Andreas Buerkert

University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

Traditional oasis agriculture in Morocco, characterised by integrated crop-livestock farming and sophisticated irrigation systems under difficult environmental conditions ensuring soil fertility, biodiversity, and subsistence livelihoods over millennia, undergoes highly dynamic changes. While wheat (*Triticum vulgare* L.) and barley (*Hordeum vulgare* L.) were mainly cultivated for subsistence needs and fodder production on rainfed land, irrigated fields are dedicated to different vegetables, maize (*Zea mays* L.), alfalfa (*Medicago sativa* L.) and fruit trees, such as citrus (*Citrus* L.) and fig (*Ficus carica* L.). Cropping patterns in oases, comprising crop rotations and mixed cropping of two or three crops, are a key determinant for the systems' sustainability. Rather than by effects of climate change, the survival of Morocco's mountain oases is increasingly determined by rural-urban transformations, including out-migration of the local population to urban centres and decreasing economic importance of oasis agriculture. This study was carried out in Tizi N'Oucheg in the High Atlas Mountains of Morocco and investigates (i) changes in cropping patterns from 1990 to 2023 through GIS-based analyses of satellite images and drone-based surveys of different growing seasons, (ii) socio-ecological and economic factors driving changes in cropping patterns, and (iii) transformation effects on soil fertility through soil sample analyses. Use of rainfed agricultural land and terraces with multiple cropping patterns decreased in recent years due to increasing market orientation, implying enhanced monocropping of specialty crops, such as potato (*Solanum tuberosum* L.) and onion (*Allium cepa* L.) on irrigated land close to the village, as well as fodder production for partly stable-fed livestock. Due to decreasing economic returns of low-input cropping systems with relatively low yields, remittances from migrated family members along with seasonal employment in cities serve as main income sources for local households. Shifting cropping patterns and increasing abandonment of agricultural land threatens soil fertility, sustainable land management practices, and preservation of traditional knowledge.

Keywords: Crop-livestock systems, High Atlas, multiple cropping, oasis agriculture, rural-to-urban, time series

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Contact Address: Youness Boubou, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: youness.boubou@uni-kassel.de

Land-use change within the western Amazon region: Analysing spatial-temporal variations on forest structure with remote sensing techniques

Raquel Capella[1], Valerie Graw[2], Daniel Callo-Concha[3]

[1]*RPTU Kaiserslautern-Landau, Environmental Sciences, Germany*

[2]*Ruhr-University Bochum, Geography, Germany*

[3]*University of Bonn, Center for Development Research (ZEF), Germany*

Human population growth, along with the increase of global demand for raw materials and agricultural commodities has historically impacted the global tropics. In the western Amazonian region, notably the market demand for Brazil-nut and later the Seringa latex (destined to rubber production) have, during the second half of the XX century, fueled large migration fluxes towards these remote and still sparsely populated forest areas. Currently, different vectors of occupation and land-use change exist and vary in terms of type and intensity across the different countries of the region. In this study, we analyse the trinational border shared by Brazil, Bolivia and Peru, which constitutes a great example of how widely those scenarios might vary across a relatively narrow geographic extent although being part of the same biome. We adopt three conservation areas as study cases – namely Extractive Reserve Chico Mendes (Brazil), Manuripi-Heath Amazonian Wildlife National Reserve (Bolivia) and Tambopata National Reserve (Peru) – in which activities as tourism, extractivism of forest products, agriculture and large scale livestock farming differently affect the local ecosystems. Here we aim to use remote sensing technologies to evaluate temporal changes on the vegetation of the three sites, not merely in terms of gain or loss of tree cover, but to assess the vegetation structure, which can then be used as a proxy of ecosystem integrity/stability. To achieve this goal, we analyse and adapt the Forest Structural Condition Index (SCI) proposed by Hansen and collaborators in 2019, based on images captured by the satellites Landsat 7 and 8, as well as canopy height data developed by the Global Land Analysis & Discovery Lab (GLAD), and processed using Google Earth Engine. The index, originally developed with the reference date of 2012, will be updated with more recent data available for 2020, therefore allowing analyses of temporal changes during the given timeframe. Such assessment aims to provide a landscape-level understanding of the of the state of preservation of the three sites, which is especially relevant on a perspective that considers, besides the ecological sphere, the other components and actors that interact within a highly interconnected social-environmental-economical system.

Keywords: Amazon, forest structure, land-use change, remote sensing

Contact Address: Raquel Capella, RPTU Kaiserslautern-Landau, Environmental Sciences, Lina-Kössler-Strasse, 76829 Landau in der pfalz, Germany, e-mail: capella.raquel@edu.rptu.de

Converting natural forests to different coffee cropping systems affects soil nitrogen transformation in tropical Thailand

Nipon Mawan[1], Phonlawat Soilueang[2], Yupa Chromkaew[2], Sureerat Buachun[3], Wiriya Sanjunthong[1], Narit Yimyam[1], Kittipong Jaikarsan[1], Nuttapon Khongdee[1]

[1]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*
[2]*Chiang Mai University, Dept. of Plant and Soil Science, Thailand*
[3]*Rajamangala University of Technology Lanna Phitsanulok Campus, Thailand*

Land-use change significantly alters nitrogen (N) transformation and retention in soil and plays crucial roles in soil fertility and greenhouse gas (GHG) emissions. This study aimed to investigate the impact of natural forest conversion to different coffee (*Coffea arabica* L.) cropping systems on soil N transformation in tropical northern Thailand. Soil samples from two depths (0–20 cm and 20–40 cm) were collected from four land uses: forest conversion to coffee monocultures (C), coffee agroforestry (FC), coffee- persimmon (*Diospyros kaki* L.) intercropping (CH) and adjacent natural forest (F). The soil labile nitrogen pools (including ammonium (NH_4^+), nitrate (NO_3), dissolved organic N (DON) contents and microbial biomass N (MBN)) were measured, as well as the soil total N (STN) concentration. Soil nitrification and N mineralisation rates were determined using a 35-day laboratory incubation experiment. The forest conversion to coffee agroforestry significantly increased soil N stock in both soil depths, but no significant difference was observed in C and CH soils as compared to F soil ($p < 0.05$). The three labile N forms (NH_4^+, NO_3 and DON content) were significantly higher under the C, FC and CH soils in the 0–20 cm depth, while the coffee monoculture decreased the MBN content as compared to forest soil in both depths. The forest conversion to all the different coffee cropping systems enhanced the net nitrification and N mineralisation rates. Interestingly, the N immobilisation process in the forest soil was higher than those in C, FC and CH soils, which indirectly regulated a decreased nitrification rate. With the exception of the FC soil, the nitrification/N immobilisation ratios in the C and CH soils were higher than those in the F soil, indicating an increased N loss risk after forest conversion. Our results indicated coffee agroforestry systems had the potential to enhance soil N content associated with forest conversion to coffee plantations, but plantations of coffee monoculture and coffee-persimmon intercropping were less effective with regard to soil N increase.

Keywords: Coffee agroforestry, land-use change, nitrification rate, nitrogen transformation

Contact Address: Nuttapon Khongdee, Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Huay Kaew Road, 50200 Chiang Mai, Thailand, e-mail: nuttapon.k@cmu.ac.th

The potential of green water for dry season cultivation of seasonal floodplain wetlands in Africa

SAHER AYYAD[1], POOLAD KARIMI[2], MATTHIAS LANGENSIEPEN[1], LARS RIBBE[3], LISA-MARIA REBELO[4], MATHIAS BECKER[1]

[1]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany*
[2]*IHE Delft Inst. for Water Educ., Land and Water Management Dept., The Netherlands*
[3]*TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics, Germany*
[4]*International Water Management Institute, Sri Lanka*

There are immense pressures on African wetlands to produce more food crops. As a result, a rapid trend of converting natural land cover into cropland has emerged across the wetlands of sub-Saharan Africa (SSA). To halt cropland expansion, which entails increased use of blue water (surface and groundwater) for irrigation and infringe on valuable protected areas, as well as to alleviate poverty and hunger, we must provide sustainable intensification and diversification strategies towards realising the agricultural potential with minimal impacts on wetlands' functions. This research advocates an efficient use of the prevailing green water (plant-available water stored in the soil) on the existing cropland areas of seasonal floodplain wetlands in SSA, typically cultivated with a single crop of rainfed lowland rice during the wet season. A methodological framework was developed to analyse the potential of crop production using available green water during the dry season in a representative seasonal floodplain wetland; the Kilombero Floodplain in Tanzania. The framework relies on open-source gridded datasets to detect green water availability and variability patterns using existing and newly developed indices.

Results demonstrated the substantial potential for increasing crop production using available green water in Kilombero. In detail, we detected about 65–70 days during the dry season where green water availability permits for cultivating short-cycled crops on at least 53 % of the total cropped area in Kilombero. Such potential permits to maximise the agricultural potential as well as farmers' livelihoods and resilience. The developed approach in this study can help guiding interventions and investments needed towards refining the cropping portfolio using green water resources while simultaneously reducing pressures on the already-scarce blue water resources in floodplain wetlands in SSA. The framework and data used are fully transferable and can be applied to other regions

Keywords: Food security, green water, remote sensing, sustainable diversification, sustainable intensification, water-food-climate nexus

Contact Address: Saher Ayyad, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Bonn, Germany, e-mail: saher.ayyad@uni-bonn.de

Comparative analysis of sustainable productive systems for the Honduran Mosquitia

Luisa Claros, Andrés Charry, Elias Bucardo, Jenny Wiegel

The Alliance of Bioversity International and CIAT, Colombia

The Honduran Mosquitia is the largest protected area in the country and is the home of over 96 thousand people between mestizos and 6 indigenous communities. This area is of high environmental importance due to its high biodiversity, key role in water provision and connectivity with the other large Mesoamerican forests, nevertheless, the region is under threat of deforestation due to the migration of "colonos", the expansion of agricultural activities and illegal timber extraction.

To tackle deforestation and empowering local communities in the conservation of their forests, various organisations, including WCS have been promoting sustainable agricultural systems to provide alternatives to illegal and environmentally impactful activities, with different levels of success. In this study we assessed and compared 5 productive alternatives that have been promoted, are currently in place or have received express interest by the local communities: cacao, timber (except from mahogany), basic staples (rice and beans), swa (*Carapa guainensis*), and allspice (*Pimenta dioica*).

We assessed the productive alternatives using seven dimensions to understand their upscaling potential, co-benefits, opportunities, risks, and challenges in multiple areas: market potential, community preferences, income generation, environmental risk and compatibility, social equity, enabling environment and nutrition improvement potential. For this, we conducted a literature review combined with focus groups with representatives of the local communities and semi-structured interviews with key experts and representatives of the different productive systems.

Our results show that given the distance and connectivity to input markets and consumption centres, all productive systems face serious challenges for their competitiveness, especially for internationally traded commodities. Nevertheless, the lack of cash generating activities available in the region (other than cattle ranching and timber extraction) poses serious threats to the livelihoods of the families and the conservation of the landscapes. An integrated approach combining the improvement of food security interventions and complementary income generating activities may be an avenue to support the families in improving their overall conditions, with cocoa and basic staples showing higher potential than the other alternatives analyzed, but the lack of access to basic services and remains a serious bottleneck that would demand non-market interventions.

Keywords: Honduran Mosquitia, participatory rural appraisal, protected areas, sustainable livelihoods, value chain analysis

Contact Address: Andrés Charry, The Alliance of Bioversity International and CIAT, Km 17 recta Cali - Palmira, Cali, Colombia, e-mail: a.charry@cgiar.org

Multi-scale time series of biophysical parameters and vegetation structure in heterogeneous landscapes of West Africa

Verena Huber Garcia, Frank Thonfeld, Jonas Meier, Ursula Gessner

German Aerospace Center (DLR), Earth Observation Center, Germany

The aim of the BMBF-funded research project CONCERT is to identify emission mitigation options for the major greenhouse gases (GHG), in parallel with improving food security in West Africa. This will be achieved – among others – through the estimation and projection of GHG emission budgets for the region using a fully-coupled regional Earth System Model (ESM), specifically adapted to the WASCAL region.

Science-based information for adaptive land management requires quantification of vegetation parameters at stand-scales, and updated high-resolution land cover and vegetation maps to upscale measured GHG fluxes to country-scales. For reliable ESM predictions of future GHG budgets and crop productivity, we need to improve our understanding of the spatial pattern and temporal dynamics of land use and land cover (LULC) in West Africa.

Satellite Earth observation can provide valuable datasets of vegetation dynamics and structure, but global products are oftentimes not perfectly suited to regions like West Africa as they are coarse in spatial and temporal resolution.

Here, we assess time series of the leaf area index (LAI) based on earth observation data at different spatial and temporal resolutions. Time series methods allow to fill gaps in the spatial and temporal domains in order to compute dense time series and assess vegetation dynamics. Time series of Sentinel–2–based LAI allow to detect multiple growing cycles with specific magnitudes and provides structural information of vegetation as an important input of ESM. Our regional focus lies thereby on Burkina Faso and Ghana and specifically on the border region between the two countries.

Keywords: Biophysical parameters, Copernicus, leaf area index, time series, vegetation structure

Contact Address: Verena Huber Garcia, German Aerospace Center (DLR), Earth Observation Center, Oberpfaffenhofen, 82234 Wessling, Germany, e-mail: verena.hubergarcia@dlr.de

Forest resource base and land use land cover dynamics in the Elgo sub-basin, southern Ethiopia

Asmelash Tesfaye[1,2], Tsegaye Bekele[2], Katharina Löhr[3,1]

[1]*Leibniz Centre for Agricultural Landscape Research (ZALF), Forestry, Germany*

[2]*Hawassa University, Wondo Genet College of Forestry and Natural Resources, Ethiopia*

[3]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*

The study aimed to investigate the small-holder farmer's dependency on forest products and the dynamics of forest resource base as a domain of land use land cover (LULC) changes that occurred between 2000 and 2021. A total of 240 household interviews and 5 focus group discussions were conducted in 12 villages of the catchment, an area where forest landscape restoration (FLR) intervention takes place since 2018. A hybrid of land cover signature and maximum likelihood algorithm was used to classify a total of 6 LULC classes. Overall, farmers are highly dependent (X2 – 57.5; P = 1.4e-10) on forest products, specifically tree biomass for energy consumption than other alternatives such as electricity, crop residues, and cow dung. Tree and bamboo products mainly used for construction, energy, and furniture are identified. These products are mainly collected from remnant natural forests > woodlots > agroforests. The latter two are the dominant farmers-managed practices even with a high tendency of expansion. Farmers are integrating an average of tree seedlings $2356 \pm 1200 \approx 0.5 \pm 0.2$ ha area converted into a tree-based farming system between 2018 and 2022. Here, the spatial distribution of these planted trees is higher (3174 ± 2140; $p = 0.004$) in the higher elevated areas of the catchment. *Eucalyptus* spp, *Cordia africa*, *Mangifera indica*, *Cuppressus lusitanica*, and *Juniperus procera* are the leading tree species. As construction and energy (X2 – 135.57; P = 2.2e-16) are the leading purposes of these tree-based practices, it vividly dictates the farmers' choice of tree species. To correlate the survey findings, LULC maps are created for the years 2000 and 2021 with overall accuracy of 67.2 % and 72.3, and Kappa coefficients of 0.57, and 0.66 respectively. Reduction in areas is observed in grassland (90.5 %), bare land (55.8 %), and heterogeneous agriculture (26 %), in contrary arable land, water bodies, and forest lands are increased by 91.1 %, 59.8 %, and 195 % respectively. The LULC changes are consent with the expansions of tree-based systems in the catchment. The implication of these tree-based systems for accessing forest products is highly noted. Thus, wider adoption of these systems by integrating the most preferred tree species is advised.

Keywords: Forest landscape restoration, Lake-Chamo catchment, land use land cover change

Contact Address: Asmelash Tesfaye, Leibniz Centre for Agricultural Landscape Research (ZALF), Forestry, Eberswalder Str. 84, 15374 Müncheberg, Germany, e-mail: AsmelashTesfaye.Gebremedhin@zalf.de

Evaluating waste management challenges, practices and habits for circular economy and green growth in Nigeria

Opeyemi Amusan[1,2], Israel Afolayan[2], Olusola Amusan[3,2]

[1]University of Ibadan, Nigeria
[2]Waste and Bio Recycling Associates League (WABRAL), BOG Intercont. Ltd., Nigeria
[3]ARKfAN Foundation, Nigeria

The importance of waste management in developing countries like Nigeria cannot be over-emphasised because of its attendant health, safety, environment, land use and socioeconomic challenges. Nigeria is the most populous African country with an ever-increasing population of over 200 million, a limited land area of 923,768 km^2 at about 150 people per km^2, and urban-to-rural population of 48.3 % - 52.7 % across six geopolitical zones. These increasing population, urbanisation and scarce resources call for a study to evaluate the waste management challenges, practices and habits for circular economy development and green growth in Nigeria. Consumption and development theories formed the theoretical framework of this study. Descriptive statistics and secondary sources of information were collected through books, journal articles and web pages of specific organisations. In addition, personal–expert knowledge of these field and study area was also used in the evaluation of waste management challenges, practices and habits for circular economy development and green growth in the country. It was found that, wastes are often burned or disposed of on landfills, open dumps and water bodies without prior treatment. Thus, waste management is a bottleneck in Nigeria because of weak or lack of enforcement of environmental regulatory policies and legislation. This may be connected with challenges like inadequate environmental awareness, poor land-use, missing recycling, producers' irresponsibility, corruption, inadequate- funding, technology and development. Established waste habits of Nigerians in hierarchy were organic/food waste (57.0 %), plastics (27.0 %), glass (5 %) and others (4 %), mostly dumped on landfills. Since organic/food waste is the highest, moving the country from linear to circular economy would improve agri-food systems, foster green growth and clean environment. Circular economy conserves resources, enhances food security, and generates new products for agri-food transformation. This study led to the establishment of the Waste And Bio Recycling Associates League (WABRAL) in Nigeria for the promotion of global circular economy best practices in Nigeria and Africa.

Keywords: Agri-food systems, circular economy, land use, waste

Contact Address: Opeyemi Amusan, University of Ibadan, P.O.Box 23039, Ibadan, Nigeria, e-mail: amusanope@gmail.com

Assessing spatio-temporal patterns of rain-fed and irrigated agriculture using time-series earth observation in Baringo, Kenya

Faith Kandie[1], Barthlomew Kuria[1], Mark Boitt[1], Harison Kipkulei[2]

[1]*Dedan Kimathi University of Technology, Inst. of Geomatics, GIS & Remote Sensing, Kenya*

[2]*Leibniz Centre for Agricultural Landscape Research (ZALF), Germany*

Food security and sustainable agriculture are part of SDG2 (Zero Hunger) and also among the five pillars of the Kenyan government Bottom-Up Economic Plan. Agriculture is the main source of food and with population increase combined with climate variability, transformation to smart agricultural practices arise, one of which is irrigation. Spatial information on existing agricultural land is vital for a framework towards irrigation. Baringo South sub-county is a semi-arid, marginalised and food-insecure area in Kenya with poor coping mechanism towards climate change. The sub-county has an irrigation potential of $180 \, km^2$ with $15.8 \, km^2$ operational in the large-scale irrigation schemes of Perkerra and Eldume while the small-holder schemes remain unaccounted for hence inadequate statistics on total irrigated land.

This study is thus aimed at assessing the spatial-temporal patterns of rain-fed and irrigated agriculture through: (i) Monitoring existing agricultural land-use employing Landsat time series for 1989–2022. (ii) Investigating the extents of irrigated land using Sentinel-2 imagery for 2022 by object-based image analysis (GEOBIA), and (iii) quantifying the importance of irrigated agriculture in food production. Other supplementary data for the study are climate data, vegetation indices and reference data for dominant irrigated, rain-fed lands and other land management practices for training and validation. Objective one results revealed fluctuations in agricultural land with the highest surge and decline of $500 \, km^2$ (1989–2002) and $300 \, km^2$ (2002–2012), respectively. The changes are attributed to anthropogenic factors causing mutual conversion with rangeland and forests. The highest overall accuracy was 89.09 % with a kappa of 0.87. Objectives two and three analysis are ongoing at reference data collection stage. For classification of both Landsat and Sentinel, the robust machine learning Random Forest Algorithm was/will be executed. These results will benefit in transforming food system through revelation of patterns, extents and significance of irrigation in food production.

Keywords: Agriculture, food security, irrigation, Kenya, forest conversion

Contact Address: Faith Kandie, Dedan Kimathi University of Technology, Inst. of Geomatics, GIS & Remote Sensing, Ngumba Drive, 00608 Nairobi, Kenya, e-mail: rjk.faith@gmail.com

Climate change

Climate change, agriculture and adaptation

Cross-geography adaptation to climate change in coffee-growing regions: Is it risk-specific or generalised?

Gina Maskell[1], Sarah Murabula Achola[2], Sabine Undorf[1], Paula Aschenbrenner[1], Christoph Gornott[3]

[1]*Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Research Department II: Climate Resilience, Germany*

[2]*University of Kassel, Agroecosystem Analysis and Modelling, Germany*

[3]*University of Kassel & Potsdam Institute for Climate Impact Research (PIK), Fac. of Organic Agricultural Sciences, Germany*

Climate change adaptation assessments are often undertaken from local to regional scale. On-farm decision-making in the face of a changing climate is driven by multiple factors and local contexts. Yet, we see parallels between implementation of certain adaptation strategies, in regions on opposite sides of the world. This can be due to global connections, information exchange, and the parallel evolvement of similar agricultural adaptation responses. Some of these agriculture adaptation responses are risk-specific, e.g. irrigation systems (risk of low precipitation events). Other adaptation responses, such as agroforestry, address general risk (including non-climatic risks). In a recent systematic review covering empirical literature on adaptation responses, the majority ($\sim 58\,\%$) of adaptation responses address the non-specific risk of "general climate change". To date, there are very few empirical cross- or multiple geography assessments of adaptation. To our knowledge none that look at the relationship between adaptation uptake and present risks. We explore the link between parallel adaptation uptake and parallel climatic risk (or hazard). Is adaptation occurring risk-specific or generalised? Is there a pattern between specific/generalised adaptation strategies and single/multi-hazard climatic trends? Looking at the case study of coffee smallholders, we analyse the relationship between regional climatic trends and adaptation measures undertaken, exemplified by coffee agroforestry or intercropping (generalised), and improved seed varieties (specific). Coffee makes an interesting case study because of the need to plan for the long-term, with a tree crop that produces for 20–30 years. We use a harmonised dataset of ~ 3000 coffee smallholder households, as part of the rural household multi-Indicator survey available for coffee growing regions in 10 countries in South and Central America, Africa, and Asia. We further use a range of climate indices derived from daily, gridded observational and reanalysis datasets including for example the fifth generation ECMWF atmospheric

Contact Address: Gina Maskell, Potsdam Institute for Climate Impact Research, Member of the Leibniz Association, Research Department II: Climate Resilience, Telegraphenberg A 62/1.08, D-14412 Potsdam, Germany, e-mail: maskell@pik-potsdam.de

reanalysis (ERA5) starting in 1950 aggregated to spatial scales relevant for comparison with the survey data. Our results offer a multi-geography analysis of the interlinkages between climate signals and adaptation patterns across coffee growing regions and conceptualise discussion on the implications for designing and evaluating effective adaptation addressing generalised v. specified risk.

Keywords: Agroforestry, coffee, cross geography, generalised adaptation

Uphill shifting cultivation under pressure: Perspectives and adaptation of tribal farmers in northeast India

Lea Sophia Schröder[1], Jürgen Scheffran[2], Uwe A. Schneider[1]

[1]*University of Hamburg, Research Unit Sustainability and Climate Risks, Germany*
[2]*University of Hamburg, Research Group Climate Change and Security, Germany*

Shifting cultivation is an extensive subsistence farming system that has been practised for centuries by tribal communities in mountainous regions of South and Southeast Asia. The integrated and organic farming system provides food sovereignty and income for tribal communities, sustains established local plant varieties, and preserves traditional knowledge and cultural practices, and thus social cohesion. However, multiple stressors threaten the future of shifting cultivation. In some places, the emigration of a more educated younger generation reduces the available labour force. In other places, an increasing scarcity of fertile lands leads to shorter cropping cycles with a higher risk of soil degradation. More intense rainfall patterns under climate change are likely to exacerbate this risk.

Despite the importance of shifting cultivation for the livelihoods of tribal farming communities, its future remains largely unexplored. This study reduces this knowledge gap and attempts to answer the research question: What shifting cultivation futures are plausible under climate and social change?

This interdisciplinary study combines diverse methods from the natural and social sciences. We use the biophysical process model EPIC to explore possible climate futures of uphill shifting cultivation in Northeast India, accounting for daily weather impacts on soil erosion risk. In addition, we conduct and assess qualitative and quantitative interviews with tribal farmers about current threats to shifting cultivation, perceived climate change impacts, considered adaptation strategies, and future perspectives.

Our results show that shifting cultivation is affected by climate and social change in multiple ways. While simulations indicate substantial increases in soil erosion by 50 % and more than 100 % under global warming levels of 2 °C and 3 °C, respectively, towards the end of the century, interviews revealed rising temperatures and delayed onset of summer monsoon precipitation as major perceived threats to cultivation. Farmers also emphasised the risk of losing traditional knowledge due to increasing off-farm activities by the younger generation. Despite these threats, they perceive shifting cultivation as a comparatively climate-resilient cropping system and important safety net, especially for resource-poor farmers. This study discusses plausible pathways of future shifting cultivation and options for adaptation.

Keywords: Adaptation decisions, climate change, Northeast India, shifting cultivation, subsistence agriculture, tribal farmers, uphill farming

Contact Address: Lea Sophia Schröder, University of Hamburg, Research Unit Sustainability and Climate Risks, Grindelberg 5, 20144 Hamburg, Germany, e-mail: lea.sophia.schroeder@uni-hamburg.de

Predicting potato diseases in smallholder agricultural areas of Nigeria using machine learning and remote sensing-based climate data

Esther S. Ibrahim[1], Claas Nendel[1], Bahareh Kamali[2], Efron N. Gajere[3], Patrick Hostert[1]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*
[2]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany*
[3]*National Space and Research Development Agency, Space Institude, Nigeria*

In many regions of Africa, severe cases of pest and crop diseases are linked to the negative impacts of climate change such as rising average temperatures and changes in precipitation regimes. The problems are prominent in Nigeria, where rainfed subsistence farming dominates and even only slight changes in climate regimes may largely affect cropping systems. Although farmers in Nigeria continue to use broad-spectrum fungicides on potato, potato diseases are still on the rise. Using remote sensing data and modeling techniques, related risks may be mitigated in the future, but a deep understanding of the mechanisms behind crop diseases or operational early-warning systems is not in place in Nigeria and most parts of SSA. Recently, machine-learning methods have become more prominent in epidemiological early warning. They provide vital information on data-disease relations useful for pre-disease infection management. Here, we build on machine-learning methods to develop spatial early warning tools for Nigeria, using the Jos Plateau as a test case. Remote sensing, as well as meteorological and field data, were used to (a) predict disease incidences using field reference data and a random forest classifier (RF), and (b) identify local conditions conducive to potato diseases, using machine-learning results based on multi-criteria classification (MCC). The results of the RF approach for 2019, 2020, and 2021 showed similar spatial characteristics, while the MCC varied significantly. Both models predicted between 72 % and 96 % of the potato fields being infested. The MCC model further revealed that spatiotemporal frequencies of vulnerability in June can be the indicator that informs the degrees of infestation. RF predictions resulted in higher levels of accuracy (between 83 % and 88 %) compared to MCC (between 67 % and 77 %), while the latter reflected the spatiotemporal patterns of annual disease incidence better. A five-day vulnerability window used with the MCC proved to be the most useful tool for developing an efficient spraying regime, based on a combination of temperature, rainfall, and relative humidity thresholds. This facilitates our development of an operational early-warning system for potato disease in tropical highlands of Africa, especially introducing spatial risks, which provides a more eco-friendly approach for early warning. This supports future smart agricultural practices and food security, increases yields, and promotes sustainable agricultural policies.

Keywords: Classification, epidemiology, modelling, prediction, random forest, spatial sensing

Contact Address: Esther S. Ibrahim, Leibniz-Centre for Agric. Landscape Res. (ZALF), Eberswalder Straße 84 , 10099 Müncheberg, Germany, e-mail: esther_shupel.ibrahim@zalf.de

Accounting for weather variability in farm management resource allocation in northern Ghana: An integrated modelling approach

Opeyemi Adelesi, Yean-Uk Kim, Heidi Webber

Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany

Smallholder farming systems in the Northern Region of Ghana are confronted with a wide range of risks related to weather variability and market volatility, among others. Together they are key reasons explaining farmers' limited investments to improve farm sustainability and productivity. Modelling can assist in understanding complex relationships and trade-offs between productivity, environment (e.g. soil fertility), and economic aspects in farm systems analysis. However, to date, few model assessments have explicitly explored the effects of weather variability on crop management and farm-level resource allocation. As crop yields and fertiliser response are highly sensitive to weather dynamics, this has implications for farm outcomes in any given year, as well as influencing subsequent investments in crop and farm management. This study introduces a new integrated modelling approach to optimise farm-level resource allocation considering annual weather-dependent variation in crop grain and biomass yields as well as annual variation in cash at hand and herd size for the case of smallholder mixed crop and livestock farming systems in northern Ghana. The integrated model combines a process-based crop model linked to a farm simulation model and an annual optimisation model. To better investigate the effects of weather, the crop model simulations are driven by a large ensemble of weather time series for two scenarios: good and bad weather. The key output from each iteration of the integrated model is an optimised resource allocation after 5 years. Considering the distributions in outputs across the large weather ensemble, the probability of farm asset increase and decrease in livestock number is determined for each of the two weather scenarios. We show that the current cropping systems in the study area operate below the economically optimised level. According to the model results, farmers could improve incomes with increased allocation of their land area to cash crops like rice, groundnut, and soybeans. Farmers have more than a 50 % probability of increasing their income over five years under bad weather scenarios when using optimised cropping patterns rather than the current cropping systems.

Keywords: Bio-economic farm model, CLEM, integrated model, mixed cropping system, northern Ghana, SIMPLACE, weather risk

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Pooling resources, pooling risk: Customary institutions in pastoral adaptation to climate change

Misginaw Arficho, Andreas Thiel

University of Kassel, International Agricultural Policy and Environmental Governance, Germany

With the growing impacts of climate change and exacerbating factors like population pressure, and resource-based conflicts, livelihood conditions of pastoral communities, who occupy the vast majority of Eastern Africa, are worsening. Given the limited capability of the national governments to reach out to such socioeconomically and politically marginalised groups, how pastoral communities adapt to the changes is increasingly becoming an important question among politicians, practitioners, and academics. This sought to address the role and the mechanism through which informal institutions facilitate climate change adaptation among indigenous pastoral communities in southern Ethiopia. Informal institutions are the most dominant in influencing the livelihoods are tied to the biophysical and socioeconomic dimensions of indigenes livelihood. By addressing key adaptation strategies and activities, the study highlights informal institutions' role in facilitating adaptation. Employing a mixed methods approach, the study examined the strategies, processes, actors, and institutions influencing resource pooling. Our data revealed that mobility, livelihood diversification, storage, resource pooling are key strategies practice at different level in different communities. We found out that institutions of animal branding and hide keeping facilitate access to a basic resource, and enhance social cohesion by clearly defining property rights, setting a display incentive among members. These factors are important to adapt to impacts of climate change in these marginalised communities living in remote parts of the country. A systematic understanding of these institutions, and the mechanism through which they enable adaptation would be a learning case for similar endeavours. Such a knowledge is particularly relevant in light of current Ethiopian government's adaptation strategy of marketisation and enhancing livelihood diversification. Recognition of such factors would shape what might be attended to when designing adaptation policy, research, and practices. Furthermore, outcomes of the study could substantiate current knowledge on adaptation studies, by highlighting the role and mechanism through which informal institutions facilitate adaptation.

Keywords: Adaptation, climate change, drylands, indigenous

Contact Address: Misginaw Arficho, University of Kassel, International Agricultural Policy and Environmental Governance, Faculty 11 - section: international agricultural policy and environmental governance, 37213 Witzenhausen, Germany, e-mail: misgina.tamirat@gmail.com

Indigenous tree species reforestation: An adaption measure to climate change in central Uganda

Estellina Namutebi[1], Joost Dessein[1], Cuthbert Tukundane [2]

[1]*Ghent University, Agricultural Economics, Belgium*
[2]*Uganda Martyrs University, School of Arts and Social Science, Uganda*

Human-induced causes of climate change in Uganda have made the country vulnerable to climate change since the dawn of the 21st century (Mafuta, et al. 2010). Among these, is deforestation which has seen three-quarters of the forest cover in Uganda exploited for agriculture and industrial development (Magala, 2015). It's these forests that assist in rainfall formation and thus better seasonal crop growing and yields among the rural farming communities. Besides, seasonal crops are the determinant of the survival of rural community farmers who are engaged in mixed farming both crops and livestock production. For that reason, the effects of climate change like long dry spells, and changing rainfall patterns, have greatly impacted the farmers in rural areas of Uganda. Being seasonal crop farmers implies that farming is entirely dependent on rainfall which is received annually between 1500–2000mm per annum in the central region of Uganda. This challenge prompted action research, which was carried out in the aforementioned area, whose intervention was indigenous tree reforestation and fruit tree growing for food security as an adaptation measure to climate change. The response from the community of interest was tremendous and thus, a gradual change of mindset toward environmental protection.

The methodology employed was participatory action research, which took four years 2018–2021. This research used the cyclical methods of action research, which involved 20 households as the community of interest. The purpose of fruit growing was meant to boost food security and nutritional diet for the households. Besides, it was a strategy to enable farmers to plant and care for the indigenous tree species. Within three years the farmers were able to harvest, Papaya, guavas jackfruit, and mangoes. By the time we concluded the four cycles, we had planted more than 5,000 trees on fragmented pieces of land (each farmer's piece of land) and a community forest with indigenous tree species on one acre of land. The action research enabled farmers not only to develop adaptation measures to climate change but also to protect the environment and its biodiversity, and thus promote co-existence in the ecosystem.

Keywords: Indigenous tree species, climate change, reforestation

Contact Address: Estellina Namutebi, Ghent University, Agricultural Economics, Coupure links, 9000 Ghent, Belgium, e-mail: estellina.namutebi@ugent.be

Encouraging farmers' response to climate change induced water stress through norm activation model among Iranian farmers

Masoud Yazdanpanah[1], Tahereh Zobeidi[2], Laura Warner[3], Katharina Löhr[4], Stefan Sieber[4]

[1]*Agricultural Sciences and Natural Resources University of Khuzestan, Iran*

[2]*International Institute for Applied Systems Analysis, Cooperation and Transformative Group, Austria*

[3]*University of Florida, Agriculture education and communication, United States*

[4]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Adaptation to climate change is a key step for ensuring that food security and diversity of the food system. Adaptation strategies in farm level involve modifying farming practice, and water management practices. However, many farmers in developing countries still continue with traditional farming methods for various reasons and are not interested in implementing adaptive innovations strategies in their farms. Encouraging and directing farmers to use these strategies is a key factor to ensure food security and achieve sustainable development. The first step is to understanding current farmer perception and behaviour. Therefore, this research aimed to examine factors affecting farmers' behavioural intention to adapt in Khuzestan Province, in southwest Iran. To achieve this goal, the current study examined applied the Norm activation model (NAM) to research the adaptation intention to climate change induced water scarcity of Iranian farmers. The data was collected through a cross-sectional survey from 250 farmers from Khuzestan, Iran. Structural equation modelling shows an excellent fit of the NAM model to the data with moderate explained variance of intention. The variance in behavioural intention explained through the NAM amounts to 33 %. The results suggest that adaptation intention is influenced directly by personal norms (β=.575, P=.000). Aspiration and responsibility (β=.294, P=.000) and awareness of consequences of water scarcity (β=.186, P=.014) are two determinants of personal norm. Farmers' personal norms could be activated by becoming aware about negative consequences of climate change such as economic and income problems, conflict between farmers, and health problems as well as through feeling responsibility for the consequences. It is more probable that farmers will be intended to do an adaptation strategy, when they feel they have a moral obligation to adapt. These results have broad policy implications that are intelligible to adaptation planning and development, notably through the amplification of personal or moral norms.

Keywords: Climate change adaptation, moral norm, moral obligation, responsibility

Contact Address: Masoud Yazdanpanah, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, 744581 Ahvaz, Iran, e-mail: masoudyazdan@gmail.com

Assessing the climate change vulnerability of rice farmers in below mean sea level regions: An agro-ecological unit-based approach

Fathima Abdulkhaderkunju[1], Archana Raghavan Sathyan[1], Sreeram Vishnu[1], Pratheesh Pradeep Gopinath[2], Thomas Kopp[3], Christoph Funk[4]

[1]*Kerala Agricultural University, Dept. of Agricultural Extension, India*
[2]*Kerala Agricultural University, Dept. of Statistics, India*
[3]*University of Siegen, School of Economic Disciplines, Germany*
[4]*Justus-Liebig University Giessen, Center for International Development and Environmental Research (ZEU), Germany*

Food security is a pressing concern in the face of climate change, particularly for the developing economies such as India. The country supports 1.39 billion people, which is 17 % of the current global population. As the world's fifth most vulnerable country to climate change, it is reported that the country could face hunger issues by 2030 due to the adverse impacts of climate change in the agricultural sector. The rice production systems in the country perform a critical role in securing the food security and the associated value chains. Hence, there is a pressing need to assess the vulnerability of the food production systems and the dependent communities to put in place appropriate adaptation measures to ensure food security. In this context, we developed a composite vulnerability index (CVIAEU) to compare the vulnerability of rice farmers in two major rice-growing below mean sea level agro-ecological units (AEUs) of the Indian subcontinent located in Kerala. The CVIAEU is based on three key dimensions of climate change vulnerability viz, adaptive capacity, sensitivity, and exposure. Each dimension is characterised by nine major components and 39 indicators specifically tailored to the rice production systems of the AEUs under consideration. A comprehensive field survey was conducted covering 263 farm households in the two AEUs, using a well-structured and pre-tested interview schedule to elicit field-level data for index construction. We find that the exposure dimension shows the greatest differences among AEUs, followed by sensitivity and adaptive capacity. Following the assessment of major components under the dimensions framework, components where interventions can be planned were identified, and policy-level suggestions were made to improve these components through training and a change in insurance policy to improve livelihood strategy diversification, credit borrowing capacity, water management, technology adoption, and flood risk management capacity. In addition, the CVIAEU framework can be extended to other rice-growing areas with necessary modifications in the selection of indicators from the indicator framework.

Keywords: Adaptive capacity, agro-ecological units, climate vulnerability, exposure, rice farmers, sensitivity

Contact Address: Archana Raghavan Sathyan, Kerala Agricultural University, Dept. of Agricultural Extension, Vellayani, 695522 Thiruvananthapuram, India, e-mail: archana.rs@kau.in

Effects of reported and observed weather shocks on crop losses in south-eastern Madagascar

Chiara Sophia Weituschat, Lisa Murken

Potsdam Institute for Climate Impact Research (PIK), Germany

Climate change is already posing numerous risks to smallholder farmers in sub-Saharan Africa. Madagascar has been particularly affected in recent years, as weather shocks such as droughts and cyclones have strongly impacted agricultural households. These households, often with limited access to resources, will need to adapt to this new and continuously changing situation. New uncertainties and risks in relation to weather shocks and climate change are already taking effect, with crop losses as a common consequence, threatening the already fragile food security of households in the region. This study analyses the impact of weather shocks on households' pre- and post-harvest crop losses. We draw on household survey data from a representative sample of 600 farming households in three regions in south-eastern Madagascar strongly affected by climate change: Atsimo Atsinanana, Anosy and Androy. Using the survey data, we explore major vulnerabilities in crop production and post-harvest processing. Reported weather shock data and observed weather data from global gridded weather data products are used to study their impact on crop losses for a broad range of major cash and food crops, such as maize, peanuts, vanilla, coffee, and rice. Additionally, we analyse implications for households' food security and use the data set's extensive information on agricultural practices and reactions to weather shocks to explore and analyse avenues and practices suitable to increase households' resilience to weather shocks. We pay particular attention to potential heterogeneity in effects. The results of this study will contribute to informing interventions directed at improving farm households' resilience and food security.

Keywords: Crop loss, food security, Madagascar, resilience, weather shocks

Contact Address: Chiara Sophia Weituschat, Potsdam Institute of Climate Impact Research, RD2 - Climate Resilience, Telegrafenberg, 14473 Potsdam, Germany, e-mail: sophia.weituschat@pik-potsdam.de

Land use diversification to fight food insecurity and improve resilience towards climate change in Ethiopia

Shibire Bekele Eshetu[1], Meselu Mellaku[2], Haftom Hagos[3], Katharina Löhr[1], Stefan Sieber[4,1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany*

[2]*Hawassa University, Wondo Genet College of Forestry and Natural Resources, Ethiopia*

[3]*University of Kassel, Inst. for Agricultural Engineering and Bioenergy, Germany*

[4]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*

In 2015, the main rainy season, locally called 'kiremt', was late and below normal conditions precipitation. Overall, the year was one of the driest in large parts of Ethiopia. Consequently, the government called for emergency assistance for 10.2 million people. In response to climate change and climate variability induced risks, rural farm households are responding in various ways, which include conversion of agricultural land use to woodlot management and adoption of agroforestry systems. This study investigates agricultural land diversification's climate change resilience capacity through tree plantation and agroforestry practice by comparing land use systems in Awi Zone, Bale Zone, and Hawassa Zuria. Data from the Central Statistics Agency (CSA), FAO reports and mapping of land use land cover changes in selected three study sites. The research considers the amount of food distributed during 2015 and 2016 as an indicator of food insecurity during the drought and FAO's priority classification for aid support. The result shows that during this period, about 149,389 households have been victims of crop damage due to reasons related to crop diseases, rainfall shifts, pests and wild animals resulting in a production loss on 28,767 hectares of land. Climate related reasons, such as frost or floods, and excess and shortage of rainfall account for about 48.5 % of the loss. Bale zone, with higher monocrop production, was under high risk of drought and classified as priority one for aid distribution even though the land size ownership of the household in the area is bigger as compared to Awi and Hawassa Zuria. Hence, monocrop production puts households at higher risk of food security due to the varying climate and crop diseases. Areas with more land use diversification using woodlot and agroforestry practices were identified as not a priority for aid supply during drought season. Hence, the diversification has backed the farmers in securing their food through income from tree harvest and other products from agroforestry practice. This supports current trends to push smallholder farmers toward diversification and introduction of agroforestry systems. However, diversification models need to be designed carefully to ensure context specific fit.

Keywords: Agroforestry, diversification, food security, land use, woodlots

Contact Address: Shibire Bekele Eshetu, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Eberswalder Strasse 84, 15374 Müncheberg, Germany, e-mail: bekeleshibire@yahoo.com

ID 606

Wastewater residues and hydrogel application: Pathways to increase water and food security in Morocco?

Manuel Krauss[1], Aziz Abouabdillah[2], Omnia El Bergui[2], Dominik Schmitz[1], Markus Biel[1], Abdellah Aboudrare[2], Ahlem Jomaa[1], Evelyn Mathyl[1], Sebastian Romuli[3], Joachim Müller[3], Fatiha Elhafiane[4], Mohamed Hafidi[4], Hafidi Youssef[5], Najim Ittobane[5]

[1]*FiW - Research Inst. for Water Management and Climate Future at RWTH Aachen e.V., International Cooperation and Capacity Development, Germany*

[2]*Ecole Nationale d'Agriculture de Meknès, Morocco*

[3]*University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany*

[4]*Institut Agronomique et Vétérinaire Hassan II, Morocco*

[5]*Moulay Ismail University, Molecular Chemistry and Organic Materials Team (CMMO), Morocco*

Drought conditions in large parts of the Maghreb negatively affect crop development and yield potential also in 2022/2023. In Morocco, drought conditions have delayed planting, reduced the area sown and resulted in below-average biomass. While hydrogels could be a way to increase water efficiency, (treated) wastewater is often used directly or indirectly for irrigation. In addition, waste water treatment by-products (treated waste water and sludge) can be used to improve soil fertility. In the framework of the Moroccan-German research project I-WALAMAR, the potential for the safe use of treated wastewater and residues from municipal wastewater treatment plants and olive mills in agriculture were investigated. The interdisciplinary project also focused on the development and application of hydrogels in field and plot experiments. In this presentation we will present the evaluation of the impact of hydrogel application on different crops in field and plot trials and discuss the potential for safe use of waste water treatment by-products (treated waste water and sludge in agriculture. Field trials in Meknes, Morocco, showed how different hydrogel applications and the use of olive oil production residues can be used to support water efficiency in food production and nutrient supply in the soil. Results varied with crop type, application rate, hydrogel type and irrigation pattern. Field studies on wastewater and effluent residues from the municipal wastewater treatment plant in Ain Taoujdate showed that the liquid and solid residues can be used safely, but only under certain conditions, such as extended storage of the sludge or post-treatment of the wastewater. Findings also showed that surface waters used for irrigation might be higher

Contact Address: Manuel Krauss, FiW - Research Inst. for Water Management and Climate Future at RWTH Aachen e.V., International Cooperation and Capacity Development, Kackerstrasse 15-17, 52072 Aachen, Germany, e-mail: krauss@fiw.rwth-aachen.de

polluted with pathogens than wastewater effluents. There is thus potential to improve water and food security in Morocco with wastewater residues and hydrogel application. The developed biodegradable hydrogels also showed good water absorbing properties. They could help increasing crop yield and to safe water resources. Furthermore, the biodegradable material could increase the sustainability of the application of hydrogels. However, there are still challenges and open questions in the concrete, safe application of these substances and work to scale up needs to be carried out.

Keywords: Climate adaptation, hydrogel, Morocco, water efficiency, water reuse

The effects of economic and environmental strategies on typical dairy farms performance in Western Kenya

Reagan Lewis[1], Nina Grassnick[2], Katrin Agethen[3]

[1]*Egerton University, Animal Sciences, Kenya*
[2]*Thuenen Institute, Coordination Unit Climate and Soil, Germany*
[3]*Thuenen Institute, Farm Economics, Germany*

Dairy farming makes a substantial contribution to economic and social development. Globally, milk production employs around 150 million people. The dairy industry, predominantly smallholder in East Africa, is the most developed of the livestock sub-sectors. Increased demand for animal-source food might support smallholder crop-livestock farmers in engaging in market-oriented economic activities by expanding livestock production practices. But it also significantly contributes to global warming contributing about 30 % of the greenhouse gas emissions in the country. and expected production growth will come along with increasing emissions. The study region is Western Kenya. This region's rainfall is bimodal, with long rains from March to June and short rains from September to December. As a result, each year has two full cropping seasons. The majority of farms are mixed crop-livestock farms, with a focus of the main economic activities on sugarcane, corn, sorghum and dairy. Rainfall, on the other hand, is exceedingly variable and unpredictable, resulting in crop losses and food insecurity. Based on a farm survey among 160 mixed dairy farms in the four counties Vihiga, Siaya, Kakamega and Homabay typical farm data sets are set up for the purpose of determining the effects of greenhouse gas mitigation on typical dairy farms performance. These data sets include the herd structure, the animal performance, feeding strategies and land use. The criteria of selecting typical farms is based on: number of dairy cows, animal production systems, breed and crop production. Greenhouse gas emissions estimation for the dairy enterprise and related crop and forage production will be applying IPCC methodology tier 2 following 2019 IPCC guidelines. The ongoing study aims at assessing the effects of greenhouse gas mitigation strategies on herd performance, farm economics and greenhouse gas emissions. The results will be able to inform stakeholders on potential side effects and co-benefits of the mitigation strategies. The study will also contribute to a flagship project of the global research alliance on agricultural greenhouse gases (GRA) called Economics of GHG mitigation at farm level in global cattle production systems.

Keywords: Climate change, dairy farms, greenhouse gas emissions

Contact Address: Reagan Lewis, Egerton University, Animal Sciences, Egerton Njoro, 20100 Nakuru, Kenya, e-mail: reaganlouis163@yahoo.com

Productive, environmental, and economic shifts of dairy systems by adopting silvo-pastoral systems and improved pastures

Ricardo Gonzalez Quintero[1], Helver Hernando Garcia[2], Jesús Fernando Florez[3], Stefan Burkart[3], Jacobo Arango[3]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Kenya*
[2]*Fudacion Alpina, Colombia*
[3]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*

In Colombia, milk yield gaps among dairy systems are large and farms with better feed quality and sustainable cattle management practices are more productive. Cattle farming is responsible for about 15 % of the Colombian greenhouse gas emissions (GHGE), therefore, sustainable mitigation strategies for dairy farms can help to reduce the climate impact. Silvo-pastoral systems (SPS) and improved pastures (IP) are recognised strategies to transform dairy systems by enhancing cattle productivity, reducing climate change impact, and increasing farm profitability. This study aims at assessing the climate change impact of small dairy cattle farms and at identifying how the implementation of SPS and IP as sustainable cattle practices (improvement scenario -IS-) can improve milk yields, farm profitability, and reduce GHGE. The study focuses on four very small dairy farms in the Cauca Department in Colombia and uses a life cycle assessment approach to calculate the carbon footprint (CF) of milk production. GHGE were calculated by applying the 2019 refinement to 2006 IPCC guidelines. The functional units correspond to one kg fat and protein-corrected milk (FPCM) and one kg live weight gain, in a cradle-to-farm-gate approach. A biophysical allocation method was applied for handling co-products leaving the farm. The study found that the milk CF ranged between 2.4 and 3.2 kg CO_2-eq kg FPCM^{-1} in the baseline. On average, in the IS, the area with SPS and IP corresponded to more than 48 % of the total farm area. The above allowed a higher availability of high-quality forage in the IS than in the baseline (no adoption of SPS and IS) and led to an increase in milk yields of up to 38 % with a subsequent reduction of up to 40 % of milk CF (varying from 1.4 and 2.7 kg CO_2-eq kg FPCM^{-1}). The IS also increased incomes by milk sales between 33 to 50 %. The study provides evidence on the positive influence that the adoption of SSP and IP can have on the transformation and improvement of the sustainability of small dairy systems in Colombia. The findings highlight the importance of sustainable mitigation strategies for dairy farms to reduce their climate impact while improving productivity and profitability.

Keywords: Carbon footprint, greenhouse gas emissions, life cycle assessment, mitigation actions

Contact Address: Ricardo Gonzalez Quintero, The Alliance of Bioversity International and CIAT, Trop. Forages Program, Kasarani rd. icipe complex, PO Box 823-00621 Nairobi, Kenya, e-mail: r.gonzalez@cgiar.org

ID 400

Drought monitoring/prediction using remotely-sensed data and SSP climate change scenarios in a Tunisian olive orchard

Mohamad Zare[1], Marius Hobart[1], Olfa Boussadia[2], Amel Ben Hamouda[2], Nadia Chaieb[2], Pierre Ellssel[3], Michael Schirrmann[1]

[1]*Leibniz Inst. for Agricultural Engineering and Bioeconomy (ATB), Germany*
[2]*Institut de l'Olivier, Tunisia*
[3]*University of Natural Resources and Life Sciences, Vienna (BOKU), Dept. of Sustainable Agricultural Systems, Div. of Organic Farming, Austria*

The increasing impact of climate change on agricultural and horticultural practices in northern Africa necessitates better predictive drought models. In this study, remotely sensed data and techniques, more specifically, analysing satellite imaginary and unmanned aerial vehicle (UAV) were applied to determine agricultural drought conditions in an olive orchard in Jemmal, in western Tunisia, using a spectral index, called vegetation cover index (VCI). Moreover, long term time series of monthly precipitation has been used to calculate standard precipitation index (SPI) with different time scales, namely, 3,6-months, as meteorological drought index. The study utilised Landsat8/9 imagery to calculate VCI as an agricultural drought index, with over 50 images obtained over three years (2020–2022). The monthly mean VCI values were considered representative of drought conditions in the presented olive orchard. The cross correlation between agricultural and meteorological drought indices was calculated with different lag times. The results showed that the agricultural drought occurred after the meteorological drought. This study used wavelet transform (WT) integrating with adaptive neuro-fuzzy inference system (ANFIS) model to simulate and predict VCI (output of machine learning model) based on SPI values with several lag times as inputs. The calibrated hybrid Wavelet-ANFIS model was then used to predict VCI using 35 climate change models under different shared socioeconomic pathway (SSP) scenarios which is developed with respect to the sixth IPCC report. Present study focuses on SSP based scenarios – span a range from sustainable and green pathway (SSP1) to ongoing growth in emissions by development of fossil-fuel (SSP5) – which are incorporated in coupled model intercomparison project-6 (CMIP6). The results can be used by farmers to plan appropriate irrigation schedules or adapted agricultural practices for upcoming droughts in semi-arid western Tunisia. Understanding the situation helps agricultural water planners to develop better insight into management policies to minimise losses in water scarcity conditions.

Keywords: Climate change, CMIP6, drought, Landsat, olive, Tunisia, wavelet-ANFIS model

Contact Address: Marius Hobart, Leibniz Inst. for Agricultural Engineering and Bioeconomy (ATB), Agromechatronics, Max-Eyth-Allee 100, 14469 Potsdam, Germany, e-mail: mhobart@atb-potsdam.de

Replacing oxen with tractors: Reduction or shift in greenhouse gas emissions?

Christian Bateki Adjogo[1], Million Tadesse[2], Shimels E. Wassie[3], Andreas Wilkes[3]

[1]*University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany*
[2]*Ethiopian Institute of Agricultural Research, Holetta Research Center, Ethiopia*
[3]*Unique Forestry and Land Use GmbH, Germany*

Cattle supply over 60 % of draft power employed to increase labour productivity in mixed crop-livestock (MCL) systems within Africa. They also emit more than 60 % of greenhouse gas (GHG) emissions from the livestock sector, such that replacing oxen with tractors has also been proposed as an emission mitigation strategy. Using survey data from Ethiopia, this study estimated and compared GHG emissions from MCL farmers pre- and post- adoption of tractor services, to elucidate the change in total GHG emissions.

Forty-eight farmers in the Arsi zone of Oromia, Ethiopia were purposively selected following consultative talks with key stakeholders (e.g., Oromia Mechanisation Office). A farmer was interviewed if he/she (i) practised MCL farming; (ii) used tractor services of local farmer cooperatives; and (iii) was willing and able to provide information on their production practices pre- and post- adoption (between 2002 and 2022) of tractor services. Employing a semi-structured questionnaire, we collected data on cattle herd structure and size, feed and manure management, as well as use of animals and tractors for crop production activities. Additionally, data on the types of crops grown, land cultivated, fertiliser and pesticide application, and yields were collected. Combining these data with information from the Oromia cattle Tier 2 GHG Inventory, we followed the IPCC Tier 2 approach and estimated the total GHG emissions from livestock and crop production activities.

On average, the total herd size of the study population decreased by 59.5 % while the land cropped increased by 36.6 % between pre- and post- adoption of tractor services. The reduction in total herd size resulted in a decrease from 0.529 to 0.224 t CO_2 equivalents (CO_2e) in livestock GHG emissions while emissions from cropping activities increased from 84.2 to 187.3 t CO_2e post adoption of tractor services. As such, the introduction of tractor services resulted in a net increase (121.3 %) in total GHG emissions within this study. These findings suggest that touching agriculture, mitigation strategies implemented at sub-sector level may not reduce emissions but rather shift emissions to another sub-sector. Therefore, GHG mitigation strategies for agri-food systems in Africa should be evaluated while keeping all sub-sectors in perspective.

Keywords: Africa, cattle, greenhouse gases, mitigation strategies, mixed crop-livestock systems

Contact Address: Christian Bateki Adjogo, University of Kassel, Animal Husbandry in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: christian.bateki@uni-kassel.de

ID 667

Spatial targeting of adaptation efforts in the livestock sector

Lucy Kimani, Rein van der Hoek, An Notenbaert

The Alliance of Bioversity International and CIAT, Kenya

Climate change has emerged as a significant threat to livestock and the ecosystem goods and services on which they depend. With projections of rising temperatures and CO_2 levels, changing rainfall patterns, and increased climate variability and occurrence of extreme events, the direct impacts of climate change on livestock can be seen through behavioural and metabolic changes, including reduced feed intake, increased energy requirement, and decreased conception rates. Additionally, indirect impacts are felt through various channels, including a mismatch between increasing water demand and decreasing water supply, increased pest and disease pressure, biodiversity losses, changes in quantity and quality of feed resources, and changes in overall system productivity and livelihood patterns.

Regions identified as the most vulnerable to climate change, such as sub-Saharan Africa and South Asia, also rely heavily on livestock for food, income, and livelihoods. Thus, adaptation is critical for these regions to cope with the multiple stresses caused by the rapidly changing climate. To address this need, we compiled spatially-explicit climate risk layers for Ethiopia, Tanzania, Kenya, Senegal, Mali, Tunisia, and Colombia and uploaded them to the Targeting Tools platform for easy access.

Targeting Tools is a web-based GIS tool (https://targetingtools.ciat.cgiar.org/) that facilitates the combination of different climate risk indicators, including bio-climatic variables, risk of droughts, floods, heat stress, flooding and waterlogging, into risk hotspot maps. The tool is user-friendly and packaged with a spatial database, making it ideal for use by students, educators, and development practitioners. Through the characterisation function of the tool, users can estimate the extent to which people, animals, and crops are exposed to climate risks and identify priority areas for adaptation action. In summary, our study provides a practical solution for supporting adaptation efforts in vulnerable regions by providing easy access to spatial climate risk information.

Keywords: Adaptation, climate risk, mapping

Economic performance and greenhouse gas emissions of two typical beef production systems in Eastern Kenya

KATRIN AGETHEN[1], REAGAN LEWIS[2], NINA GRASSNICK[3]

[1]*Thünen Institute, Farm Economics, Germany*
[2]*Egerton University, Dept. of Animal Sciences, Kenya*
[3]*Thuenen Institute, Coordination Unit Climate and Soil, Germany*

Kenya has one of the major cattle populations in Eastern Africa, of which around ¾ are beef cattle. Especially for households in the arid and semi-arid regions of Kenya, beef cattle production is an important economic activity. Located in less favourable production environments, low opportunities for cropping or dairy production exist. The production systems in arid and semi-arid lands suffer climate change more directly, being less resilient to weather shocks. At the same time, they are a hotspot of greenhouse gas emissions per kilogram produced. In the recent past, Kenyans' meat consumption has been rising, with beef representing 77 % of the annual intake in 2019. The expected further increase due to economic growth and a growing population offers economic opportunities to local producers. Despite the importance of developing pathways for sustainable beef production, only little data is available, particularly on the farm-level economics and greenhouse gas emissions related to the specific beef production systems. Based on the typical farm approach, we identified two beef production systems in Eastern Kenya: a pastoral beef production system and an agropastoral production system combining beef production with cropping. Data has been collected through expert interviews and producer focus groups in Isiolo County for the pastoral beef production system and in Kitui County for the agro-pastoral beef production system. We carried out an analysis of the economic performance, including factor use, production inputs, and farm outputs. We estimate the greenhouse gas emissions associated with beef production at farm-level by applying tier 2 IPCC 2019 methodology. Based on literature research and expert information, we model locally appropriate production scenarios addressing herd management and feeding strategies. In an ongoing analysis, we assess their impacts on economic performance and greenhouse gas emissions and discuss potential co-effects between climate change mitigation and adaptation. Our results contribute to the understanding of beef production at farm-level and identify leverages for more sustainable beef production in typical Eastern Kenya production systems. This study contributes to a flagship project of the Global Research Alliance on Agricultural Greenhouse Gases (GRA), called Economics of GHG mitigation at farm level in global cattle production systems.

Keywords: Beef production, climate change mitigation, farm economics, greenhouse gas emissions

Contact Address: Katrin Agethen, Thünen Institute, Farm Economics, Bundesallee 63, 38116 Braunschweig, Germany, e-mail: katrin.agethen@thuenen.de

ID 449

Climate change impacts on the agro-climatic suitability of major food and cash crops in Madagascar

Anna Hampf

Potsdam Institute for Climate Impact Research, Adaptation in Agricultural Systems, Germany

Madagascar is one of the most food-insecure countries in the world with almost half of its population suffering from undernourishment. In 2019–21, an exceptional drought caused by well-below average rainfalls led to massive failure of the country's main food (rice, cassava, maize and sweet potato) and cash (coffee, sugarcane, vanilla and cloves) crops. Although climate change only played a limited role in this drought, early adaptation planning is crucial to increase the resilience of mainly rain-fed agriculture. Here, we assessed the impact of climate change on the agro-climatic suitability of major food and cash crops in Madagascar using the Crop Ecological and Environmental Requirements (EcoCrop) model. Ecocrop is a mechanistic model that uses monthly temperature and precipitation data and characteristics to determine the suitability of a crop to be grown in a specific location. Model calibration was done based on input from local experts and literature, as well as, high-resolution CHELSA-W5E5 meteorological forcing data. The model performance was tested against data of harvested area at district level. ISIMIP3b climate data that provides bias-corrected CMIP6 climate forcing for ten global circulation models and three SSPS (SSP1-RCP2.6, SSP3-RCP7.0 and SSP5-RCP8.5) was used for future model runs. Model results indicate that the agro-climatic suitability of both food and cash crops is likely to decrease under global warming scenarios, however, with some regions and crops being less affected. The largest decrease in suitable land was simulated for rice, particularly in parts of the Taomasina, Mahajanga and Antananarivo province. Coffee suitability was simulated to decrease mainly on the central eastern coast of Madagascar, remaining suitable in the country's north. Possible adaptation potentials could be the substitution of rice cultivation by maize or cassava in the northern part of the country. Simulation results also suggest that the expansion of sweet potato cultivation is a suitable adaptation option as this crop is less affected by climate change. It can be concluded that crop production in Madagascar is likely to become more challenging under climate change and that appropriate adaptation strategies are needed to increase income and food security among a highly vulnerable population.

Keywords: Climate change, coffee, simulation

How do extreme climate events affect farm food production? An analysis from Brazil

Deise Maria Bourscheidt[1], Daniel Alberto Perozo-Suárez[2], Elder Antônio Tomassevski[3]

[1]*Universidade Federal da Fronteira Sul, Dept. of Economic Sciences, Brazil*

[2]*University of Brasilia, Dept. of Economics, Brazil*

[3]*Western Paraná State University, Dept. of Agricultural Sciences, Brazil*

Agriculture expansion in Brazil has continuously grown for the last three decades, at least. Such expansion has affected indigenous communities living in forest areas and the environment, also increasing climate change effects. From a global perspective, there is evidence of the relevance of these effects on the agricultural sector itself: between 2003 and 2013, most damages from extreme climate events like droughts and floods were suffered by the global agricultural sector. In the same way, most of these damages took place in developing countries. Considering this view, developing countries with strong agricultural sectors were considered relevant case studies. In this sense, this work aims at analysing the incidence of extreme climate events and how they affect farm food production in Brazil, under a multi-hazard assessment approach and correlation analysis. To do this, the losses from extreme climate events and their implications on the agricultural sector were explored. Results indicate that changes generated by agricultural expansion at the country level have had a positive economic outcome but with strong impacts on traditional communities and the environment. In addition, negative effects resulting from natural disasters and extreme climate events showed greater losses in economic and infrastructural terms in the last years of the study. In sum, the economic trade-off between the increasing agricultural expansion and the corresponding long-term environmental and economic impacts is negative, which suggests a counterproductive effect of agricultural expansion for the future of agriculture itself. The study suggests the adoption of solutions based on technology for productivity growth and the adoption of risk management strategies as policy recommendations.

Keywords: Agricultural expansion, Brazil, extreme climate events, farm food production.

Contact Address: Daniel Alberto Perozo-Suárez, University of Brasilia, Dept. of Economics, Campus Darcy Ribeiro, 70910-900 Brasilia, Brazil, e-mail: keemoen@gmail.com

Prioritizing climate-smart cattle farming practices and technologies for sustainable livestock production in Colombia's Orinoquia region

Alejandra Marin, Alejandro Montoya, Isabel Cristina Molina, Jacobo Arango

The Alliance of Bioversity International and CIAT, Colombia

The Orinoquia region in Colombia is home to diverse ecosystems, including forests and various agroecological zones, but extensive cattle ranching poses a significant challenge as it contributes to deforestation and threatens the region's valuable forest resources. To address this issue, there is a growing interest in promoting low-carbon land use and practices that increase adaptation and resilience to climate change.

Climate-smart cattle farming (CSCF) integrates adaptation, resilience, and mitigation strategies to ensure sustainable and profitable productivity. This study aimed to identify, evaluate, and prioritise CSCF practices and technologies for the Orinoquia region in Colombia in a participatory manner. The framework developed for the study involved a first phase of identification and evaluation of CSCF practices and technologies based on evidence from the literature, followed by a second phase of classification and prioritisation of practices through participatory processes with key stakeholders in the region. CSCF practices were evaluated and ranked by five pillars: productivity, mitigation, adaptation, economic feasibility, and ease of implementation (perception pillar). Indicators analysed included animal stocking rate, weight gain, duration of practice evidence, enteric methane emission intensity, soil carbon stock, establishment costs, and forage production in high and low precipitation seasons, ease of implementation, and level of interest in the practice by the producers.

The study found that intensive silvopastoral systems for browsing, improved pastures plus rotational grazing, and grazing management practices represented the CSCF options with the greatest productive, environmental, and economic benefits. These practices can help promote a productive, profitable, and climate-adapted livestock sector in the region. The participatory approach used in the study can also facilitate alignment between sectors and policies and help develop farmers' capacities and knowledge to make climate-smart choices in their livestock production systems. In conclusion, promoting climate-smart cattle farming practices is crucial for ensuring sustainable and profitable productivity in the Orinoquia region of Colombia. The participatory approach used in this study can help identify, evaluate, and prioritise CSCF practices and technologies that are productive, profitable, low-carbon and climate-adapted.

Keywords: Adaptation, climate change, mitigation, Orinoquia, sustainable livestock farming

Contact Address: Alejandra Marin, The Alliance of Bioversity International and CIAT, Cali, Colombia, e-mail: a.marin@cgiar.org

Climate change impacts on maize yields in Cameroon as mediated by heat-tolerance adaptation

Lennart Jansen

University of Kassel, Agroecosystem analysis and modelling, Germany

Sub-Saharan Africa is projected to be exposed to above-average climate change and possesses thereto substantial exposure to climate change hazards, especially in its agricultural sector, so adaptation will be necessary to safeguard food security. This is urgent, because tropical and subtropical maize production regions approach critical temperature thresholds in the growing season already in today's climate. Adaptation requires an understanding and assessment of potential impacts of climate change on crop production and possible adaptation options. These can be studied using process-based crop models. Here, the agricultural production systems SIMulator APSIM was used to model climate change impacts on maize in Cameroon in a spatially disaggregated, grid-based approach as to represent Cameroon's diverse agro-ecological zones. This was done for the two climate change scenarios SSP1–2.6 and SSP3–7.0 for the time period 2020–2100. The impact of heat tolerance adaptation in maize was assessed by parametrising one unadapted baseline variety and one synthetic heat-tolerant variety in APSIM and comparing yield outcomes. Model performance was satisfactory, and results indicated major yield losses for unadapted maize under both climate change scenarios. Yield losses were highest in Cameroon's semiarid north and under the high emissions scenario SSP3–7.0 in which case national mean yield losses exceeded 60 % compared to the baseline period 1995–2015. Climate change impacts on maize yield could be dominantly attributed to heat stress. Heat tolerance adaptation substantially mitigated yield losses under climate change and also led to yield increases in the baseline period, indicating the presence of limitations to maize yield due to heat stress already now. Mean yield gains conferred by heat tolerance adaptation were over 0.5 t ha^{-1} and yields of the adapted cultivar were higher than for the baseline cultivar in all time periods and for both scenarios. The magnitude of the gains however was time- and scenario-dependent. When compared to the baseline period, yields of the adapted cultivar still substantially declined under the high emissions scenario after 2050, which implies insufficiency of heat tolerance adaptation alone for completely mitigating impacts of severe warming in tropical maize production regions.

Keywords: Adaptation, APSIM, Cameroon, climate change, crop model

Contact Address: Lennart Jansen, University of Kassel, Agroecosystem analysis and modelling, Nordbahnhofstraße 1a, 37213 Witzenhausen, Germany, e-mail: lennart.jansen@uni-kassel.de

Non-local cattle breed farmers' perception of climate variability and adaptation strategies in Benin

Cossi Ulriche Afatondji[1], Thanh Thi Nguyen[2], Eva Schlecht[3], Luc Hippolyte Dossa[1]

[1]University of Abomey-Calavi, Fac. of Agricultural Sciences, School of Science and Technics of Animal Production, Benin

[2]University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

[3]University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany

In response to the growing demand for livestock products, zebu cattle breeds from the semi-arid Sahelian zone, perceived as "high milk-producing", such as Gudali, White Fulani, M'Bororo, and Azawak, have been increasingly introduced into various livestock production systems in central and southern Benin. However, in these sub-humid and humid zones, these breeds are facing environmental and anthropogenic challenges that may prevent them from expressing their full production potential. This study aimed to document the perception of keepers of non-local cattle breeds of the impacts of climate change on their cattle keeping and analyse possible adaptation strategies. Randomly selected 305 keepers of non-local cattle breeds were interviewed with a questionnaire in three vegetation zones (Guineo-Congolese, Guineo-Sudanian and Sudanian) of Benin. Comparing respondents' perceptions to recently published climate trends showed that a majority was aware of a decrease in rainfall pattern (74.4 %) and of an increase in temperature (88.2 %). Perceptions did not differ between vegetation zones and agreed with rainfall and temperature data recorded during 1990–2020. In the surveyed herds, White Fulani (34.0 %), Gudali (20.4 %), Azawak (6.3 %) and M'Bororo (1.9 %) were encountered along with crossbreed zebu X taurine (28.4 %) and shorthorn taurine breeds (9.0 %). According to the respondents, the observed climatic changes negatively impact milk yields (99.7 %), herd reproduction (97.0 %), herd size (74.1 %), and threaten livestock productivity (92.5 %). In response to these negative impacts, respondents mentioned to increase crop residue feeding (80.7 %), continue long-distance herd mobility practice despite its ban (20.0 %), and shift to local taurine breeds (14.1 %). A logistic regression analysis revealed that vegetation zone and breed composition of the herd determined the choice of herd mobility. Keepers with more than 60 % White Fulani in their herd were 23 times more likely than others to

Contact Address: Luc Hippolyte Dossa, University of Abomey-Calavi, Fac. of Agricultural Sciences, School of Science and Technics of Animal Production, 01 BP 526, Cotonou, Benin, e-mail: dolhip@yahoo.com

practice mobility. However, long-distance mobility has been disrupted and is restrained to areas spared from rising insecurity caused by militant Islamist groups. In addition to climatic variability affecting forage availability, dwindling access of mobile herds to available pasture could be another important factor that hinders the expression of the performance potential of non-local breeds.

Keywords: Adaptation strategies, climate variability, logistic regression, non-local cattle breeds

Climate-related risk modelling of banana xanthomonas wilt (BXW) disease incidence within cropland area of Rwanda

Julius Adewopo[1], Regina Kilwenge[2], Svetlana Gaidashova[3]

[1]International Institute of Tropical Agriculture (IITA), Natural Resource Management, Rwanda

[2]International Institute for Tropical Agriculture (IITA), Natural Resource Management, Kenya

[3]Rwanda Agricultural and Animal Resources Board, Banana Programme, Rwanda

Banana Xanthomonas Wilt (BXW) is the major threat to banana in Rwanda, causing up to 100 % yield loss. There are no biological or chemical control measures, and little is known about potential direction and magnitude of its spread, so cultural control efforts are reactive rather than proactive. In this study, we assessed BXW risk under current and projected climate, to guide early warning and control by applying maximum entropy (Maxent) model on 1,022 georeferenced BXW datapoints and 20 environmental variables. We evaluated the variables' significance and mapped potential risk under current and future climates to assess spatial dynamics of the disease distribution. BXW occurrence was reliably predicted (mean validation AUC ranging from 0.79–0.85). Precipitation of the coldest quarter, average maximum monthly temperature, annual precipitation, and elevation were strongest predictors, explaining 21.1 %, 13 %, 12.6 %, and 9.4 % of the observed incidence variability, respectively, while mean temperature of the coldest quarter has the highest gain in isolation. Further, the most susceptible regions (in western, northern, and southern Rwanda) are characterised by elevation (1,350 m - 2,000 m), annual precipitation (900 mm - 1700 mm), and average temperature (14 °C - 20 °C), among other variables, suggesting that a consistent, rainy, and warm climate is more favourable for BXW spread. Under future climate, the risk is predicted to increase and spread to other regions. We conclude that climate change will likely exacerbate BXW-related losses of banana land area and yield, under temperature and precipitation influence. Findings support evidence-based targeting of extension delivery to farmers and national early warning for timely action.

Keywords: Banana, climate change, decision-support, digital innovation, early warning, risk, xanthomonas wilt

Contact Address: Julius Adewopo, International Institute of Tropical Agriculture (IITA), Natural Resource Management, c/o KG ST7, Kigali, Rwanda, e-mail: j.adewopo@cgiar.org

Weather and climate information use and needs for rice production, cross river state, Nigeria

HILDA CHIA ETA

University of Calabar, Dept. of Agricultural Extension and Rural Sociology, Nigeria

Agriculture in developing countries is climate dependent. Consequently, climate and weather forecasts have the potential to assist small scale farmers make informed decisions that will boost the quality and quantity of crops produced. Contrarily, climate and weather information disseminated are often in forms that are ill-suited for use by small scale farmers. This study sought to investigate weather and climate information use and needs for rice production in Cross River State, Nigeria. It adopted a multistage sampling procedure resulting to the selection of 125 rice farmers. A set of structured questionnaire was employed to elicit information from farmers. Descriptive and multinomial logistic regression analysis were used to analyse the data. Results showed that the majority (57.6 %) of rice farmers were males, 47.2 % had attained secondary education, and 32.8 % were not aware of available weather and climate information in the study area. Major types of weather/climate information used for rice production were: onset/length of rainy season (86.4 %), sunshine duration (84.8 %), end of rainy season (83.2 %), daily temperatures (81.6 %), and wind direction (80.8 %). Weather and climate information that significantly aided decision making in rice production were: information on onset and end of rainy season ($\bar{x}$=4.34), forecasts on extreme weather events like floods and/or droughts ($\bar{x}$=4.33) and chances of wet spells ($\bar{x}$= 4.14). Rice farmers' key weather information needs were identified as: information on how to cope with risk and uncertainty (95.2 %), information on water management especially during dry season (92.8 %), soil nutrient management information (92.8 %), and information on how to reduce the negative consequences of weather/climate on rice production (92.8 %). Significant constraints to farmers' use of weather/climate information were: inadequate access to climate information ($\bar{x}$=4.43), inadequate money to buy radio, television, cell phones, batteries, ($\bar{x}$=4.36) and absence of electricity or unreliable power supply ($\bar{x}$=4.34). The binary logistic regression model showed that educational level ($p = 0.033$) and farming experience ($p = 0.043$) had significant positive effects on the use of weather and climate information at $p = 0.05$. The study recommended that weather and climate information providers should present weather and climate in readily accessible and practical forms to enhance uptake by farmers.

Keywords: Rice farmers, weather and climate information needs, weather and climate information use

Contact Address: Hilda Chia Eta, University of Calabar, Dept. of Agricultural Extension and Rural Sociology, Calabar, Nigeria, e-mail: hildajens@yahoo.com

Resilience and adaptation to climate change

Online posters

Perspectives on premier pathways for sustainable intensification of agriculture in Africa

Shem Kuyah[1], Adewole Olagoke[2], Ingrid Öborn[3], Frank Chidawanyika[4], Emily Poppenborg Martin[2]

[1]*Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya*
[2]*Justus Liebig University of Gießen, Inst. of Animal Ecology and Systematics, Germany*
[3]*Swedish University of Agricultural Sciences (SLU), Crop Production Ecology, Sweden*
[4]*International Centre of Insect Physiology and Ecology (ICIPE), Thomas Odhiambo Campus, Kenya*

Sub-Saharan African (SSA) countries are disproportionately confronted with low agricultural yields and other associated challenges, which are exacerbated by global environmental changes. To feed the growing population, agriculture is being intensified and expanded, even in the marginal areas that are more vulnerable to such changes. However, expansion and intensification of agriculture are known to substantially contribute to climate change, especially in areas where climate-smart agricultural practices are not common. To effectively create a sustainable change in the sector, novel user-focused technologies need to be developed, tested, and applied to different local contexts across SSA. Simply put, innovative technologies will be decisive in transitioning agriculture toward greater sustainability. Yet, choosing suitable practices is not trivial, mainly because of the context-specificity of information on innovations with potential to contribute to the sustainable intensification of smallholder farms. Literature abounds with a mix of anecdotal evidence and empirical studies with conflicting conclusions. To bridge this gap, this talk provides an overview of options for further intensification of smallholder farming in Africa by evaluating existing opportunities for increasing yields, creating resilient production systems and reducing carbon footprint. A case study will be highlighted to underscore the importance of participatory design and validation, including citizen science. We will show how continuous engagement with stakeholders increases our knowledge of regional-level systems and their needs, and supports the co-creation of regionally adapted pathways. Using examples from the UPSCALE project (https://upscale-h2020.eu/), we will discuss how multiple approaches can be combined to offer systemic solutions that can make agriculture in Africa more sustainable, and how these solutions can be fully integrated into regional-level climate adaptation and mitigation strategies, enabling resource conservation and circular approaches. Further, innovative technologies that can be further intensified to build multifunctional solutions that meet the pressing needs of food, fuel, and fiber will be discussed. We will then provide an appraisal of the necessary framework conditions for the selected solutions to succeed, based on empirical values from the examples and targeted multi-actor knowledge exchange.

Keywords: Agroforestry, circular approaches, integrated agroecology, regenerative agriculture, resource conservation

Contact Address: Shem Kuyah, Jomo Kenyatta University of Agriculture and Technology (JKUAT), 62000, 00200 Nairobi, Kenya, e-mail: kshem@jkuat.ac.ke

Potential for the adoption and use of climate-informed agro-advisories by smallholder farmers in a dryland district of Tanzania

Jacob Emanuel Joseph[1,2], Anthony M. Whitbread[1], Reimund P. Rötter[2]

[1]*International Livestock Research Institute (ILRI), Tanzania*
[2]*University of Goettingen, Dept. of Crop Sciences; Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany*

Climate variability has a substantial impact on the productivity, sustainability, and resilience of dryland farming systems. Studies have shown that smallholder farmers can enhance the sustainability and resilience of their farming systems by properly utilizing climate information services (CIS). However, smallholder farmers in the Kongwa district in central Tanzania and similarly in most dryland regions of Tanzania, are still far behind in terms of co-creation, adoption, and usage of CIS to reduce climate-related risks and increase crop yields. This study assessed the major challenges faced by smallholder farmers in the Kongwa district in adopting and utilizing CIS. To this end, a forecast-based digital advisory tool called iSAT was piloted prior to and during the growing season, to demonstrate how to meaningfully access CIS, improve on-farm decision-making, increase resource use efficiency, and achieve better climate risk management. To gain a deeper understanding of the issues that smallholder farmers are confronted with, focus group discussions and household surveys were undertaken. Climate records were analysed to establish thresholds and triggers for various on-farm decisions, with the results used to refine the design and operationalization of iSAT. We found that accessibility, reliability, and timeliness were the primary issues limiting farmers' effective uptake and usage of CIS. Other issues were illiteracy and a lack of location-specific content to assist farmers in properly managing climate risks in agricultural production. More than half of the challenges were attributed to the inefficiency of CIS providers. An evaluation of the effectiveness and efficiency of iSAT in addressing these limitations found that farmers in intervention villages managed climate risks better than farmers in control villages. The growing awareness and interest among farmers in adopting and utilizing CIS provide an opportunity for the public and private sectors and policymakers to re-evaluate and innovate CIS delivery to empower farmers to better manage climate risk. Based on our findings and those from other studies in similar production environments in India, Kenya, and Senegal we conclude that iSAT, the tool developed and tested in the study area, presents a viable model for delivering climate-informed agro-advisories to smallholder farmers.

Keywords: Agro-advisories, climate change and variability, climate information services, seasonal climate forecasts, smallholder farmers

Contact Address: Jacob Emanuel Joseph, International Livestock Research Institute (ILRI), Dar es Salaam, Tanzania, e-mail: j.emanuel@cgiar.org

Practising agroecology strengthens farmers' perceived ability to cope with climate change

Amritbir Riar[1], Alexander Heer[1], Rajwinder Riar [1], Leone Ferrari[1], Tanay Joshi[1], Ibrahim Hamadou[2], Veronica Massawe[3], Jous Clément[4], Etienne Basset[5], Monika Messmer[1]

[1]*Research Inst. of Organic Agriculture (FiBL), Switzerland*
[2]*University of Bern, Inst. of Plant Sciences, Switzerland*
[3]*SWISSAID Tanzania, Tanzania*
[4]*SWISSAID Chad, Chad*
[5]*SWISSAID, Switzerland*

Integrating agroecological practices into farming systems can improve farming systems' resilience, but reported effects vary across geographies and production systems. Enhancing the resilience of farming systems by introducing new agroecological practices comes with positive and negative tradeoffs. Farmers' decision to adopt new agroecological practices or additional agroecological practices is driven by factors such as other resource availability and/or return on investment. In addition, farmer decisions are sometimes driven by motivational factors rather than return on investment. We hypothesise that farmers' awareness about their ability to cope with climate change is correlated with the number of agroecological practices followed by farmers. To assess the farmers' perception of their ability to cope with climate change and which agroecological practices they followed, we surveyed 3038 farmers in rural regions of Chad, India, Niger, and Tanzania. Survey questions were standardised in preliminary focused group discussions with farmers and other stakeholders. Individual interviews were conducted with the respondents chosen through systematic sampling, irrespective of their farming practices or other demographic factors. Correlations between agroecological practices, gender, and the farmers' perspectives on climate change were investigated using the FactoMineR package in R. The share of female farmers' participation in the survey was 50.0 %. Prevalent production systems in the regions are rainfed and organic by default. Thus, most farmers mentioned a change in rainfall patterns as the most challenging adverse climate change in past years, followed by more disease incidences, increased temperatures, and droughts. Crop rotation, Intercropping, mulching, and crop diversification are the leading agroecological practices for farmers in the regions. About 70 % of farmers in the regions perceive that they cannot cope with climate change. Farmers' perception of their ability to cope with climate change strongly correlates with the number of agroecological practices they follow. On average,

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the perceived ability to cope with climate change was high for the farmers who practised one more agroecological practice than fellow farmers. This signifies the importance of integrating agroecological practices into farming systems to enhance their ability to cope with climate change. More country and gender-segregated results will be present to help site-specific decisions making by practitioners and policymakers.

Keywords: Agroecology, biophysical and socio-economic factors, climate change

Behavioural traits and resilience to droughts among farming households in Thailand

Robyn Blake-Rath, Rasadhika Sharma, Ulrike Grote

Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Germany

Climate change, in the form of intensified environmental shocks, adds significantly to existing challenges of small-scale farming households, especially in developing countries. Depending on the resilience capacity, households can adopt various response strategies, influencing their ability to maintain assets and how they are converted into income and broader development. Therefore, determinants pertaining the household's choice of response strategies demand attention. Literature identifies household financial and social capital as important determinants. However, evidence on the role of human capital, especially behavioural traits, is scarce. These have shown to influence behaviours and attitudes, affecting socio-economic life. Most findings on behavioural traits and resilience are based on data from developed countries and may not hold in the context of emerging economies. Therefore, the aim of this paper is to investigate the role of behavioural traits in the household's choice of response strategies to droughts in rural Thailand. In particular, we examine (i) how behavioural traits influence the decision of households to adopt absorptive, adaptive or transformative strategies and (ii) how they act as mediators. We use primary household level data on approximately 2,000 households from the Thailand Vietnam socio-economic panel project from 2017 and 2019, in combination with spatial precipitation data to also obtain causal effects. We consider a set of nine response strategies, three for each resilience capacity, together with seven measures of behavioural traits. A generalized structural equation model is executed in order to estimate direct and mediating effects. Our results show that while behavioural traits play a minor role in the uptake of absorptive strategies, they significantly influence the household's decision in regard to adaptive and transformative strategies. As mediators, risk preference is negatively influenced by droughts and household income is positively related to the trait openness and negatively to neuroticism. We can also confirm income as a consistent predictor for response strategies. As a result, the role of behavioural traits should be acknowledged in policy and intervention designs together with increased human capital investments. Potentials resulting from long-term responses, especially following severe droughts, should be fostered, in order to enhance resilience of small-scale farming households in developing countries.

Keywords: Behavioural traits, environmental shocks, farming households, household decision-making, resilience

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Contact Address: Robyn Blake-Rath, Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: blake-rath@iuw.uni-hannover.de

Climate resilience of family livestock farmers with silvopastoral system

Ingrid Romero[1], Roberto Scoz[2], Adriana Bussoni[1]

[1]*Universidad de República (UdelaR), Agronomy College, Dept. of Social Sci., Uruguay*
[2]*Independent Consultant, Uruguay*

Resilience is the ability of a system to withstand and recover from adverse conditions. The scientific community attributes three capacities to resilience: the capacity to absorb shocks (absorption), the capacity to adopt new strategies (adaptation), and the capacity to transform (transformation). The work aims to identify the resilience against extreme weather events of family farmers with silvopastoral systems (SPS). Semi-structured in terviews were conducted, asking them about their perceptions of climate change and the actions they have taken. Producers perceive longer summers and winters, changes in frost and rainfall patterns, greater solar intensity and an increase in extreme weather events. Drought was mentioned by 72 % of the respondents as the main adverse event with the greatest multiplier effect of damage: lack of fodder, low pregnancy rate, reduction in stocks, and sales with economic damage, i.e. the productive capacity of the system is damaged. The most common strategy for coping with drought is to reduce stocking rates, wean cows early and purchase rations and bales. The absorptive capacity of the system in the face of this event is to have water from wells and cutwaters, although this does not solve the loss of feed availability from the natural field, it does reduce productive damage such as loss of environment. Producers with SPS show a lower perception of vulnerability, recover faster after an adverse event, show greater diversification of income within the production system, i.e. they show greater adaptation. The practices implemented by producers with SPS in the face of adverse climatic events are: rotational grazing, subdivision of paddocks, livestock management, improvement of natural fields, and water management. It can be concluded that producers who are more open to the adoption of new technological practices are generally more resilient, particularly in terms of greater absorption and greater adaptation. The resulting conditions cannot be attributed to a single factor, such as the adoption of SPS, but rather to a series of measures adopted by the producer in recent years. The factors that increase the resilience of family farms and allow these producers to remain in the production system should continue to be studied.

Keywords: Adaptation, climate change, drought, rural producers, Uruguay

Resilience and agroforestry options in rural Zambia: Identifying the vulnerable and tailoring support to their aspired future

Luzia Deissler[1], Kai Mausch[2], Ulrike Grote[1]

[1]*Leibniz University Hannover, Inst. for Environm. Economics and World Trade, Germany*
[2]*Center for International Forestry Research (CIFOR)-World Agroforestry (ICRAF), Nairobi, Kenya and Bonn, Germany*

In the face of various global challenges, particularly climate change, smallholder agriculture needs economically, ecologically, and socially sustainable concepts. Investigating how individuals, households and communities react to and deal with adverse shocks today, while planning for better futures, can support the promotion of innovative and sustainable practices. As part of the World Agroforestry's Fruit Tree Portfolio (FTP) project which promotes nutrition sensitive agroforestry options, we collected data from 745 rural Zambian smallholder households in early 2022. We aim to support the identification of farmers who can benefit from specific resilience building practices, while assessing their potential and specific interests to adopt such practices. We first analyse smallholder farmers' resilience to adverse shocks by performing a multivariate regression on three interrelated resilience indicators (life satisfaction, recovery time and loss per shock). We find positive correlations between resilience and more diverse income portfolios (reduced recovery time and loss), higher educational attainment (higher life satisfaction; lower losses) and more developed networks (reduced recovery time). In addition, a household shows an increasing resilience to adverse shocks with an increasing number of experienced shocks. We then apply an innovative multidimensional framework for livelihood strategies to assess the potential of smallholder households to adopt agroforestry as a resilience building practice. We conduct k-means cluster analysis for the three resilience variables, identifying three clusters (low, medium, high resilience). High resilience is correlated with a lower likelihood of being poor (Poverty Probability Index), more diverse income sources, an aspirational focus on the acquisition of productive assets, but low overall ambitions, as well as a high number of memberships by the respondent and lower crop diversity on farm. Households with low resilience show high aspirations, fewer income sources and focus on private life improvement rather than acquiring productive assets. By including livelihood aspirations of farmers, next to other socio-economic household and farm characteristics, the framework provides a clearer and more context-specific evaluation for ex ante analyses of target groups for agroforestry projects. This allows development agencies to approach interventions in a more inclusive manner by incorporating farmers' views directly into the design of transdisciplinary development projects.

Keywords: Aspirations, livelihood strategies, resilience, smallholder farmers, Zambia

Contact Address: Luzia Deißler, Leibniz University Hannover, Inst. for Environm. Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: deissler@iuw.uni-hannover.de

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Community-led interventions buffer effects impacts of extreme drought drylands: A case of Turkana county, Kenya

Francis Oduor[1], Irene Induli[1], Beatriz Herera[2], Irmgard Jordan[1], Céline Termote[1]

[1]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya*
[2]*University of Hohenheim, Inst. of Social Science in Agriculture, Chair of Communication and Adivisory Services in Rural Areas, Germany*

Kenyan drylands, largely inhabited by (agro-)pastoralists born out of the need for livelihood diversification, are estimated to occupy 80 % of the total land mass. These areas face a different challenge - long history of political and economic marginalisation, frequent, recurrent droughts, poor access to markets and other services, among others. These inequalities are exacerbated by the impacts of climate change. The need for community driven food system transformation, not only responsive to the local needs but also adapted to the local context, is thus a timely endeavour.

This study applied a cluster randomised control study with 10 intervention community units (CUs), and 7 control units in Turkana county. A community led-initiative identified solutions to local problems identified at baseline in August 2020, amidst COVID-19 (n=400). Among the solutions, kitchen gardening was identified and implemented by all communities. Two CUs implemented poultry rearing and four CUs village savings and loaning associations (table banking), in addition to gardening. Approximately nine months after end of supervised implementation, in August 2022, at the height of the most severe and longest witnessed drought in the history of Kenya, a mixed-method impact evaluation study was conducted.

At baseline and endline dietary intakes and dietary diversity of women and children is very low and shows even a decrease in the mean dietary diversity scores of women and children from baseline to endline from 2.42 ± 0.97 to 2.06 ± 1.19 for children and 2.51 ± 0.98 to 2.16 ± 16 for women, respectively. Difference-in-difference models reveal however that the intervention CUs were significantly less affected by the impact of drought, with a 0.41 and 0.36 statistically significant higher mean dietary diversity score in children and women, respectively, compared to the control. Food group analysis reveal increased consumption of pulses, vegetables and fruits in the CUs compared to control. Focus group discussions associated these changes to adoption of new practices in production, preparation and consumption of food and changes in the financial cash flows of the households.

Kitchen gardens impacted positively on dietary diversity and buffered against impacts of drought significantly although it was a new activity for most participants.

Keywords: Community led-participatory initiative, dietary diversity, drylands, food system

Contact Address: Francis Oduor, The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Africa Hub – Nairobi Office, 00621 Nairobi, Kenya, e-mail: f.oduor@cgiar.org

Food system resilience: Conceptualisation and empirical application

MARGHERITA SQUARCINA

Georg-August-University Göttingen, Agriculture and Rural Development Department, Germany

In the last decades, resilience has emerged as a compelling concept for understanding social and ecological systems in the face of shocks. Although different conceptualisations of resilience exist in the literature, a consensus on its definition has not yet been reached. Furthermore, resilience analyses have focused only on specific living standards or selected components of food systems, failing to capture the whole system complexity.

There are three main approaches to measuring development resilience, which define resilience as a capacity, as a normative condition, and as a return to equilibrium. However, none of them provide a reliable measurement to guide and evaluate development resilience interventions.

This study aims to fill the upward-mentioned literature gaps by proposing and empirically testing a measure of resilience that addresses three dimensions of a food system: economic profitability, environmental sustainability, and adequate nutrition. The proposed model combines the "resilience as capacity" approach developed by FAO with the conceptualisations of resilience as a normative condition and return to equilibrium. The model considers multiple levels, from individual to community, and uses LASSO regression to select the observable variables that enter the model.

As outcome variables, we consider the probability that each of the three dimensions of the food system in the aftermath of the shock is at least at the same level as before the stressor. In this way, we integrate the "return to equilibrium" approach into the model. When the outcome is defined in terms of a threshold, the "normative condition" approach is implemented. To test the model empirically, a cross-country analysis is conducted, using data over at least two points in time from different sources, combining household surveys with GIS data.

The contributions of this study are four. First, it provides a conceptual framework of food system resilience that combines the three different approaches proposed by the literature so far. Second, it uses a food system approach that takes into account environment and nutrition in addition to the development aspect of resilience. Third, it tests the model empirically. Fourth, it uses a technique for measuring resilience that allows for flexibility and adaptability.

Keywords: Food systems, resilience, shocks

Contact Address: Margherita Squarcina, Georg-August-University Göttingen, Agriculture and Rural Development Department, Heinrich-Düker-Weg 12, 37073 Göttingen, Germany, e-mail: margherita.squarcina@uni-goettingen.de

Household nutritional resilience against climate variability in the Karamoja border region of Kenya and Uganda

Caroline Kawira

University of Nairobi, Food Science, Nutrition and Technology, Kenya

The main objective of this study is to assess household nutritional resilience against climate variability in the Karamoja border region of Kenya and Uganda. There are several specific objectives which are:

i. To assess the state of household food and nutrition security of households within the Karamoja border region of Kenya and Uganda.

ii. To determine households' resilience against climate variability in relation to socio-economic and demographic characteristics of households.

iii. To evaluate the barriers and enablers to household nutritional resilience in the study region.

iv. To evaluate interventions for nutritional resilience of households in the study region.

Both quantitative and qualitative research methods will be used. Quantitative data collection was done in the wet and dry seasons and focused on these key nutritional and food security items: HFIAS (household food insecurity access scale), MAHFP (months of adequate household food provisioning), 24-hr recall and anthropometric measures. Analysis will be done with R. Qualitative data collection will use KIIs and FGDs (with the questioning route designed on the basis of data from the baseline quantitative survey). Analysis for qualitative data will be done using Nvivo.

Expected outcomes are:

i. Assessment of the state of household food security and nutritional status in the study region.

ii. Households' resilience against climate variability in relation to socio-economic and demographic characteristics of households, food security and nutrition status in the study region.

iii. Effects of climate variability on household nutritional resilience in the study region.

iv. Interventions that promote nutritional resilience in the study region

Keywords: Climate variability, Kenya, nutritional resilience, qualitative research, quantitative research, Uganda

Contact Address: Caroline Kawira, University of Nairobi, Food Science, Nutrition and Technology, P.O. Box 472, 60200 Meru, Kenya, e-mail: kawiracarol@gmail.com

Gambian farmers' perception of and access to climate services on early warning and adaptation

Sheriff Ceesay[1,3], Fatima Lambarraa-Lehnhardt[2], Mohamed Ben Omar Ndiaye[3]

[1]*West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Gambia*

[2]*Leibniz Centre for Agricultural Landscape Research (ZALF), Farm Economics and Ecosystem Services, Germany*

[3]*Cheikh Anta Diop University (UCAD), Fac. of Economics and Management Sciences (FASEG), Senegal*

Climate variability and extreme weather are the main contributors to the current increase in global food insecurity. As global temperatures rise, extreme climatic conditions will become more frequent and severe. Using seasonal weather forecasts and early warning systems will enable farmers and households to adjust their production plans and take measures to account for expected weather events. Linking early warning to early action is particularly vital in the agriculture sector.

In agriculture, an estimated 5–10 % of domestic agricultural losses are due to changes in weather. A one-meter rise in sea level would effectively submerge up to 8 % of the country's land area. In the Gambia, these phenomena are reflected in a significant drop in harvest, water shortage, and worsening of health crises, resulting in growing food insecurity and threatening the progress made in the fight against poverty in the last decades. Studies show that obtaining and using weather forecasts can reduce the impact of weather shocks by 10–30 %.

If climate information is available but does not enable households to adopt adaptation strategies their value will be lost. Therefore, this study is set to assess how access to climate information services enables households to adopt climate risk adaptation strategies.

The binary logistic regression model is used to analyse household access to and the usefulness of the information for decision-making while the multinomial logit (MNL) model is used to analyse the perceptions of the usefulness and reliability of early warning and weather forecasting information. The recursive bivariate probit (RBP) model is used to analyse the determinant of the use of climate information and its impact on adopting an adaptation measure.

This research results show the level of access to climate information services in the Gambia, and the main factors that influence access to climate information. How farmers perceived the usefulness and reliability of early warning and weather forecasting information. The impact of the use of climate information on the adoption decision of farmers.

Keywords: Access, adaptation, climate services, climate variability, early warning, perception, The Gambia

Contact Address: Sheriff Ceesay, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Brikama, Banjul, Gambia, e-mail: ceesay.s@edu.wascal.org

Building resilience to climate change: Addressing smallholder farmers' food security concerns in Nepal

Giri Prasad Kandel[1], Miroslava Bavorová[1], Ayat Ullah[1], Prajal Pradhan[2], Bernard Kwamena Cobbina Essel[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Economics and Development, Czech Republic*
[2]*Potsdam Institute for Climate Impact Research, Germany*

Global climate change is a major threat to the sustainability of the agricultural sector. As a result of climate-related extreme events, food insecurity is steadily increasing worldwide. Food insecurity was higher among agricultural households (especially smallholder farmers) than among non-agricultural households. Smallholder farmers are particularly vulnerable to food insecurity due to their high dependence on agriculture for income and livelihoods. Nepal is a country characterised by smallholder agriculture, high poverty rates and high food insecurity. Food insecurity is a daily problem, especially for households living in remote areas of the country. Several climate change adaptation options are being adopted by some smallholder farmers to increase crop productivity, household income and food security. These adaptation options involve either staying in agriculture or abandoning it in order to improve the food security status of their households. The objective of this study was to examine the impact of climate change and adaptation strategies on the food security of smallholder households in Nepal. To achieve this, data was collected from 400 farming households in three agro-ecological zones of Nepal - Mountain, Hilly and Terai - in 2021. The study found that approximately 12 % and 22 % of farming households were classified as food insecure according to their food consumption score and reduced coping strategies index, respectively. Results from ordered logit models indicated that climate change, particularly drought, had a negative impact on food security, while adaptation strategies such as irrigation, agroforestry and temporary migration had a positive impact on food security. The study also found that factors such as education, access to markets, credit and information play a role in household food security. We recommend that any adaptation strategy to address food insecurity should be carefully designed to fit the socio-economic, climatic and institutional structures of each agro-ecological zone.

Keywords: Adaptation strategies, climate change, extreme weather events, food security, Nepal

Contact Address: Giri Prasad Kandel, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Economics and Development, Kamycka 1281, 16500 Prague, Czech Republic, e-mail: kandelg@ftz.czu.cz

Water and well-being: How access to irrigation influences food security among smallholder farmers

Prapti Barooah, Muzna Alvi

International Food Policy Research Institute (IFPRI), India

Access to water is a critical part of nearly all aspects of sustainable development. In the Indian context, over 50 per cent of the country's net sown area is rainfed and around 78 percent of India's rainfall is received during the monsoon season. Agriculture in the country continues to be heavily rainfall dependent. However, over the years, climate change has had a direct impact on the onset of monsoon in India which in turn has led to significant shifts in farming practices. Further, such shifts have a bearing on the nutrition and food security of the vast majority of rural farming households in the country. Recent studies also suggest that as much as 80 percent of smallholder farmers in India will be affected by climate hazards by 2050 and vast areas of land that are currently under rainfed cultivation could become non-arable exacerbating food insecurity. We use data from a large-scale survey with over 2000 farming households in Gujarat, a large state in western part of India with around two-third population involved in agriculture and allied activities, to understand the relationship between irrigation and household food security towards enhancing resilience of smallholder farmers in India. Gujarat is also one of the six Indian states that have been identified as extremely vulnerable to climate change impacts. The primary respondents are women farmers who are affiliated with Self-Employed Women's Association (SEWA), one of the largest women's trade unions in the country. We use linear probability estimation to look at what determines access to irrigation and the relationship between access to irrigation facilities and crop diversity and household food security. We administered the FAO's Food Insecurity Experience Scale (FIES) to assess household food security. We find that ownership of irrigation pumps is positively associated with crop diversity. Further, households that reported ownership of pumps are less likely to suffer from food insecurity. Our results highlight the need for interventions aimed at leveraging small-scale irrigation to enhance resilience and improve nutrition and health outcomes.

Keywords: Climate change, food security, India, irrigation, resilience, women farmers

Climate Information and demographic influence on climate-smart agricultural technology adoption in Ghana

Obed Kwaku Mahama[1], Abdul-Basit Tampuli Abukari[1], Osman Tahidu Damba[1], Powell Mponela[2], Mustapha Alasan Dalaa[3], Ghislain Tepa-Yotto[4], Robert Zougmoré[5], Manuel Tamo[4]

[1]*University for Development Studies, Fac. of Agriculture, Food and Consumer Sciences, Ghana*

[2]*The Alliance of Bioversity International and CIAT, Ghana*

[3]*International Institute of Tropical Agriculture (IITA), Ghana*

[4]*Université Nationale d'Agriculture (UNA), Ecole de Gestion et de Production Végétale et Semencière (EGPVS), Benin*

[5]*The Alliance of Bioversity International and CIAT, Senegal*

Climate-smart agriculture (CSA) has become a touchy subject among all stakeholders in developing countries such as Ghana. Despite all efforts to promote the CSA to achieve sustainable yields, boost food and nutrition security, and adapt to and mitigate climate change, farmers involvement is low. Stakeholders and other value chain actors, such as credit and service providers, are withdrawing in large numbers as a result of the agriculture risk trend. This study, therefore, seeks to suggest that beyond the adoption of CSA practices, farmers have to express their prioritisation of the adopted CSA practices. Stakeholders can therefore focus on adopted practices that are prioritised by the farmers to ensure increases and sustainable adoption of these CSAs. Descriptive statistics, multivariate probit, and the multinomial probit model were used to examine the extent to which farmers have adopted and prioritised CSA practices, as well as the factors of both adoption and prioritising. It was discovered that the determinants of CSA practices are best observed when the practices are prioritised. The study also revealed that not all adopted practices were prioritised, indicating that adoption is based on additional factors but not solely on utility maximisation. This alters farmers' perceptions of the improvement of these practices, which influences their continuous use of the practices. The CSA practices that were prioritised (climate-information improvement, leguminous crop rotation, organic improvement of soil health, pest/disease tolerance varieties, and stress-tolerance varieties) had significant determinates. This was based on the farmer's maximal associated benefit of practice, as they prioritised the ones they adopted. The study discovered that the five prioritised practices were climate-information improvement; leguminous crop rotation; organic improvement of soil health; pest/disease tolerance varieties; stress-tolerance varieties were good for stakeholder investment. The study recommends that, the level of CSA prioritisation by farmers who are the end users of CSA practices should be considered by government and stakeholders in their action plans.

Keywords: Adoption, climate-smart agriculture, CSA practices, determinants

Contact Address: Osman Tahidu Damba, University for Development Studies (UDS), Dept. of Agricultural & Food Economics, Nyankpala Campus, Tamale, Ghana, e-mail: otdamba@gmail.com

Farmers' adaptation behaviour to climate change: The case of central Colombia

Alexander Cano

Justus-Liebig-University Gießen, Intern. PhD Program for Agricultural Economics, Bioeconomy and Sustainable Food Systems, Germany

Some of the effects of climate change on the agricultural sector include changes in weather patterns, changes in land suitable for specific crops, water availability as well as changes in yields, among others. The literature on farmer adaptive behaviour has been increasing in recent years; however, this area has been little studied in Latin American countries. To fill this knowledge gap, twelve villages were visited in the central region of Colombia; In four out of these 12 villages three or more landslides had occurred, in four other villages two or more droughts had been experienced, and in the last four neither of these two climatic emergencies had occurred. A total of 360 farmers were visited and a lab-in-the-field was conducted. Simulating a radio broadcast, half of the farmers received information about climate change, how it affects the agricultural sector, and what is forecast for this region. Based on the protection motivation theory, farmers' perceptions of their vulnerability, the severity of climate change, and the costs of adaptation were measured, as well as their psychological distance.

Using four common agricultural adaptation measures in the region (protection of water sources, agroforestry or agrosilvopastoral practices, soil cover, and retaining walls) and three monetary measures (diversifying off-farm income, borrowing money from a financial institution or buying some type of insurance, and borrowing money from a relative, friend or neighbour), farmers' perceptions of the effectiveness of these measures as a form of adaptation, their self-efficacy in practicing them, and their intention to use them were measured. This study is expected to find that farmers' experiences with climate emergencies (landslides and droughts) will reduce their psychological distance to climate change. Likewise, it is expected that access to information will have an effect on their perception of severity and vulnerability and will influence their intention to adapt.

Keywords: Adaptation behaviour, climate change, Colombia, farmers

Contact Address: Alexander Cano, Justus-Liebig-University Gießen, Intern. PhD Program for Agricultural Economics, Bioeconomy and Sustainable Food Systems, Max-Reger-Straße 1, 35392 Gießen, Germany, e-mail: alexander.cano@agrar.uni-giessen.de

Assessing the mitigation potential of nutrient blocks made of tropical tree and legumes

Johanna Mazabel Parra[1], Isabel Cristina Molina[1], Jacobo Arango[1], Alexander Hincapie[1], Jose Igor Hleap Zapata[2]

[1]International Center for Tropical Agriculture (CIAT), Colombia
[2]Universidad Nacional De Colombia, Sede Palmira, Colombia

Fruits and leaves of tropical trees and legumes are highly nutritious and serve as a valuable source of essential nutrients for animal feed. Additionally, since trees and legumes are native to many tropical regions, they can be grown and maintained with fewer resources and lower costs than other feed options. Nutrient blocks are important for providing supplemental nutrition to ruminants when grazing on low-quality forage or during feed scarcity, promoting growth, and maintaining rumen health. This study aimed to evaluate the *in vitro* gas production and methane (CH_4) concentration emitted from grass-based diets and nutrient blocks made from tropical tree fruits, legume leaves and pods. The nutrient blocks were prepared using fruits from *Enterolobium cyclocarpum* (Ec), leaves of *Tithonia diversifolia* (Td), and leaves (Ll) and pods (Lp) of *Leucaena leucophela*. The experiment involved measuring fermentation parameters at two-time intervals (24 h and 48 h) using a grass diet (75 %) and nutrient blocks (25 %), with *Urochola brizantha* cv. Toledo (Ub) serving as the basal pasture. A total of nine treatments were evaluated, including T1: Ub+BC (commercial nutritional block used as control); T2: Ub+BM (mixed block with equal proportions of all tropical tree fruits, legume leaves and pods tested); T3: Ub+Ll; T4: Ub+Lp; T5: B.Control (100 % commercial nutritional block); T6: B.Mixed (100 % mixed block); T7: B.Ll (100 % block made from Ll); T8: B.Lp (block made of 100 % Lp), and T9: GT (100 % Ub used as comparator). The nutritional blocks, prepared with tropical tree fruits, legume leaves and pods, contained in average 3.9 times more crude protein than the control block and the grass alone (314, 83.2 and 78.1 g CP kg⁻¹DM, respectively), and the average of neutral detergent fiber content was lower in all blocks than in the pasture alone (366 vs. 664 g NDF kg⁻¹DM). The results of the experiment revealed that the treatments had a significant impact on ruminal degradation and gas production when the pasture was incubated with the nutrient blocks. Specifically, the inclusion of tree and forage products in the blocks led to an average reduction in net CH_4 concentration of 13 % and 21 % per degraded dry matter at 24 h and 48 h of fermentation, respectively.

Keywords: Animal feed, methane, native fruits, rumen fermentation

Analysis of adaption strategies for minimising the effects of climate change by smallholder farmers in Laikipia county, Kenya

Florence Achieng' Opondo, Poti Abaja Owili

Laikipia University, Kenya

Climate change has been identified as the greatest threat to agricultural production. In Kenya, farming activities heavily depend on rainfall. In the recent past, planning for farming activities has been a challenge due to either too much rain or inadequate. Huge losses on crop production and livestock have been recorded by farmers especially during prolonged dry season. To address the grave and adverse effects of climate change, the Laikipia County Government developed a strategic plan through which farming households were encouraged to diversify crop production and livestock keeping. They were also advised to adopt fast maturing and drought tolerant crop varieties and practice on-farm adaptation practices such as harvesting of rain water and practicing climate smart agriculture. Despite these noble efforts, food security is still a challenge in the County. It is not clear the extent to which farmers have adopted and implemented the proposed strategies. Therefore this study sought to analyse the adaptation measures by farming households in Laikipia County. The objectives of the study included: to determine the extent of adaption strategies for changing temperatures and variability in rainfall. The population of the study consisted of farmers' in Laikipia County, Kenya. A sample size of 384 was obtained using four multi-stage random sampling design. The total number of respondents was 346 which represented 90 percent of the targeted total sample. Descriptive statistics was used in the analysis. For changing temperature, the respondents adopted crop diversification (14.5 %), fast maturing crops (7.8 %), and undertaking irrigation farming (5.78 %). For variability in rainfall, the respondents adopted early planting (21 %), crop diversification (43 %) and planting fast maturing plants (8 %). The study recommends that more extension officers should be deployed to assist farmers in undertaking crop diversification, especially fruits and high value crops, and embrace water harvesting initiatives during heavy rains and use the water to irrigate their crops during the dry season.

Keywords: Adaptation practices, climate variability, crop diversification, fast maturing crops

Contact Address: Florence Achieng' Opondo, Laikipia University, Laikipia, Kenya, e-mail: fopondo@laikipia.ac.ke

Wheat rhizosphere bacteriome to heat stress for developing resilient wheat cultivars to sustain food security

Ashly Arevalo[1,2], Hannes Karwat[2], Frank Rasche[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*CIMMYT, Global Wheat Program, Mexico*

Heat stress is a significant abiotic stress that affects wheat crop productivity worldwide leading to potential risks under food security in the next decades promoted by climate change. In recent years, research has focused on understanding the mechanisms by which rhizosphere bacteria enhance plant adaptation to heat stress. Bacteria act with plants synergistically to play an essential role in plant growth, development, and adaptation to heat stress. While understanding of how the plant microbiome is shaped is steadily increasing, only a modest number of studies have explored the composition of the rhizosphere bacteriome of wheat-tolerant to heat stress events and its contribution to plant resilience. To address this issue, we analysed the functional composition of the rhizosphere bacteriome to four contrasting wheat genotypes under heat stress in two crop cycles at the CIMMYT CENEB experimental research centre and breeding station in the Sonora desert of Mexico. Total DNA was isolated from Rhizospheric soils (0–30 cm depth) collected from two field trials on heading + 12 days and heading + 10 days growth stages respectively, and the rDNA 16S V4 hypervariable region was sequenced employing next-generation sequencing technologies based on Illumina (MiSeq and Rapid Mode Hiseq). This approach of understanding the diversity, composition, and functional properties of the rhizosphere bacteriome will help as a baseline to understand the molecular mechanisms underlying the plant-bacteria interactions that promote genotype adaptation to heat stress events. The results of this research would allow the potential use of wheat rhizosphere bacteria for enhancing plant adaptation to heat stress and developing resilient wheat cultivars for adaptation and contributing to sustainable agriculture to face climate change.

Keywords: Adaptive mechanisms, climate change, food security, resilient cultivars, sustainability

Contact Address: Ashly Arevalo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 13, 70599 Stuttgart, Germany, e-mail: aslarevaloro@unal.edu.co

Adoption of technologies to increase the resilience of smallholder farmers in Zambia

Lutangu Andrew Litia, Tomáš Ratinger

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

Smallholder farmers are currently facing various challenges related to climate change. There is low productivity and food insecurities are rising due to crop failure caused by floods, drought, and pests. Many climate smart agricultural technologies (CSAT), such as conservation farming, have been introduced to farmers by the public and private sectors. To what extent these technologies have enhanced resilience, improved agricultural productivity, reduced food insecurities, increased household incomes, and improved the land to continue supporting rural livelihoods remains the critical knowledge gap for most researchers and policymakers.

The objective of this study is to investigate the knowledge transfer process of technologies in dealing with climate change while assuring high and sufficient crop productivity, whilst fostering a sustainable agricultural system. Specifically, the study will: i.) Identify technologies promoted and practised either from traditional or as a result of research, ii.) Investigate how farmers learn about alternative CSAT considering private, public, and NGO initiatives, and the role of communities, iii.) Investigate the attitudes of farmers towards CSAT alternatives identified, iv.) To draw policy lessons for the public, private sector, and civil societies.

The study will try to use the multidisciplinary framework that will include the sustainable livelihood framework (SLF) with the francophone agrarian system analysis approach and the development anthropology.

The study will be conducted in the Kalomo and Monze districts of the southern province of Zambia. Both lie in the agroecological zone I where rainfall is below 1000 mm. These areas are most hit by droughts and floods, with agriculture being the main activity for the local population. These areas are the maize basket of the nation.

Keywords: Climate change, climate smart agricultural technologies, crop productivity, food security, precipitation, soil

Contact Address: Lutangu Andrew Litia, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Kamýcká 129, 165 00 Prague, Czech Republic, e-mail: litia@ftz.czu.cz

Adoption of climate-smart agriculture in smallholder agri-food systems transformation in Kara, Togo: Tradeoffs and synergies

Jane Maureen Ngonjock Ebako[1], Daniel Callo-Concha[2,3], Oliver Frör[3], Sabine Schlüter[1], Peron A Collins-Sowah[4]

[1]*University of Applied Sciences Cologne, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Germany*

[2]*University of Bonn, Center for Development Research (ZEF), Germany*

[3]*University of Kaiserslautern-Landau (RPTU), iES Landau, Inst. for Environmental Sciences, Germany*

[4]*Potsdam Institute for Climate Impact Research (PIK), Research Department 2, Germany*

Climate change threatens food production systems and smallholder farmers' livelihoods, particularly in developing countries. Farmers' exposure to weather changes such as prolonged drought, late start of rains, and shifting rainfall patterns cause income loss and threaten their households' food security. Climate-smart agriculture has been heralded as a sustainable approach to increasing agricultural productivity while adapting to and mitigating climate change. There is a need to understand the full range of benefits derived from the climate-smart agricultural practices and technologies promoted to farmers in areas already exposed to several agricultural intervention projects. This requires an evaluation of agricultural production, farmers' responses and their farm management practices at the household level. Our study closes this gap by employing cross-sectional studies to identify the drivers of farmers' adopted climate-smart agricultural practices and their impact on the households' food production. We also assess factors affecting climate-smart practices in transforming agri-food systems to increase farm households' food security. We used a mixed-method approach to collect primary data in the Kozah prefecture of Togo. Quantitative data was obtained from over 500 farm households, and qualitative data was obtained from focus group discussions and expert interviews. The data were collected between January and March 2023. We want to foster discussions on the way forward with agricultural intervention projects to increase food security for smallholder farmers. First analyses already show that farmers mainly adopt soil management climate-smart practices; over 90 per cent of farmers do not use improved seeds, mainly due to the costs associated with their adoption. The results also show that farmers combine climate-smart practices on the same plot and find the impact of this combination on their food production to be increased yet risky. We anticipate that findings from this study can provide information to guide policymakers in designing agricultural programmes and policies that can better address the constraints of low food productivity and high food insecurity plaguing the country.

Keywords: Climate-smart agricultural practices, food security, smallholder farmers

Promotion of climate risk insurances for smallholder farmers: Insights and learnings from Zambia

Mika Ache

University of Duisburg-Essen, Inst. for Development and Peace (INEF), Germany

The Republic of Zambia is a country strongly characterised by agriculture. In many cases, the agricultural potential is not fully utilised and the harvests thus remain comparatively low. This can be attributed to a variety of factors. One of these factors is that Zambian agriculture is predominantly seasonal and relies on rainfall. The rainfall having become more and more irregular and irreliable, this makes Zambian smallholder farmers in particular extremely vulnerable to weather-related crop failures caused by droughts and/or floods. At the same time, Zambia is particularly exposed to the impacts of climate change. The frequency and intensity of both drought and flood events have increased significantly in recent years.

To address this issue, the Zambian government, supported by various actors like GIZ or WFP, is working on the introduction and dissemination of climate risk insurances (CRIs), for vulnerable smallholder farmers as one aspect of a wide range of measures to sustainably strengthen the resilience of this population group. GIZ's CRIIZ project to promote CRIs was oriented towards different needs and interests. On the one hand, the product of CRIs should give smallholders the opportunity to pooländ öutsourcethe risk of extreme weather-related crop failures. On the other hand, microfinance institutions (MFIs) and banks also have an interest to insure that smallholders do not find themselves in the position of being unable to repay (micro)loans they have taken out due to such crop failures. However, micro or small loans play a central role in giving smallholders access to sufficient and better-quality agricultural inputs, such as seeds or fertiliser. The Zambian government also has an interest in strengthening the country's agricultural sector, and for insurance companies, CRIs offer a potentially lucrative market due to the almost non-existent supply.

To investigate the acceptance and effectiveness of this approach on the part of smallholders and on the part of MFIs and insurance companies, various focus group discussions with smallholder groups, but also intensive interviews with employees of MFIs and insurance companies were conducted by a team from INEF (University of Duisburg-Essen). The central findings of this research will be presented here.

Keywords: Agricultural finance, climate risk insurance, smallholder farmers

Contact Address: Mika Ache, University of Duisburg-Essen, Inst. for Development and Peace (INEF), Finkenstraße 7, 47057 Duisburg, Germany, e-mail: mika.ache@uni-due.de

Differences in livelihood resilience between diversified and intensified smallholder farms in Java, Indonesia

Reinhard Rebernig[1], Arini Utami[2], Michael Hauser[1], Lorenz Probst[1]

[1]*University of Natural Resources and Life Sciences (BOKU), Dept. of Sustainable Agricultural Systems, Inst. of Development Research, Austria*
[2]*Gadjah Mada University, Dept. of Agricultural Socio-Economics, Lab. of Agricultural Resource and Environmental Sciences, Indonesia*

Smallholders in Central Java, Indonesia, have responded to dynamic markets and climate change by intensifying or diversifying agriculture and by engaging in off-farm work. Exploratory evidence from the Banjarnegara regency in Central Java, Indonesia, suggested that communities located close to each other and similar in socio-ecological dimensions (including land and household sizes and bio-physical factors) have either intensified horticulture or diversified into agroforestry-livestock systems. Our goal was to learn from this unique case how each adaptation pathway impacts livelihood resilience. We define resilience through its three dimensions buffer capacity, capacity for learning and adaptation, and capacity for self-organisation. All three can be considered livelihood outcomes. In the empirical study, we investigated whether smallholders in the two selected communities have indeed predominantly intensified or diversified, and if so, how these adaptation pathways affect resilience. In collaboration with local actors, we collected data from 78 households that were randomly sampled from all identifiable farm households in the two communities. We used the CHAID decision tree model and quantile regressions as the main strategies to analyse the data. We found that the livelihood strategies in the two communities differed significantly, corresponding to intensification and diversification pathways. Applying indices for the three dimensions of resilience, we found that households pursuing diversification scored significantly higher in all resilience dimensions and the overall resilience index. Our findings imply that diversified agroforestry may be a viable livelihood strategy in the region. The study also adds substance to the debate on agricultural adaptation and the conceptual discourse on resilience.

Keywords: Agroforestry, central Java, diversification, intensification, livelihood resilience, smallholder

Contact Address: Reinhard Rebernig, University of Natural Resources and Life Sciences (BOKU), Dept. of Sustainable Agricultural Systems, Inst. of Development Research, Peter-Jordan-Straße 76/i, 1190 Vienna, Austria, e-mail: r.rebernig@students.boku.ac.at

Addressing future food demand in The Gambia: Can increased crop productivity and climate change adaptation close the supply-demand gap?

Tony Carr[1], Felicity Addo[2], Amanda Palazzo[2], Petr Havlik[2], Katya Pérez-Guzmán[2], Zakari Ali[3], Rosemary Green[1], Genevieve Hadida[1], Alcade Segnon[4], Robert Zougmoré[4], Pauline Scheelbeek[1]

[1]*London School of Hygiene & Tropical Medicine, Department of Population Health, United Kingdom*

[2]*International Institute for Applied Systems Analysis, Austria*

[3]*MRC Unit The Gambia at the London School of Hygiene and Tropical Medicine, Gambia*

[4]*The Alliance of Bioversity International and CIAT, Senegal*

The Gambia faces numerous food system challenges, including growing food demand, climate change, land degradation, low agricultural productivity, and a high dependence on food imports that are at risk from external shocks. To address these challenges, there is a need to increase domestic food production while limiting deforestation. In this study, we used the FABLE Calculator, a food and land-use system model, to simulate scenarios for future food demand and increasing domestic food production. We considered the impacts of climate change on crops, the implementation of climate change adaptation techniques, as well as the potential of enhanced fertilisation and irrigation to boost crop productivity, and assessed whether these measures would be sufficient to meet the projected increase in food demand.

Our results suggest that relying solely on increasing crop production will not be sufficient to meet national food demand by 2050. In the absence of increased imports, cropland expansion, or prioritising domestic food crops over export crops, a significant supply-demand gap will emerge. However, investing in the scaling-up of productivity-enhancing farming techniques could potentially halve this gap. Such investments would require a substantial increase in fertiliser application and irrigation technologies. To ensure adequate food supply and minimise the need for further cropland expansion, it is crucial to improve trade by diversifying partners and addressing barriers. Moreover, as dietary habits potentially shift towards healthier diets, domestic production and trade require further adjustments to accommodate the increased demand for nutritious food groups.

Our study highlights the urgent need for sustained investment and policy support to comprehensively enhance domestic crop production and trade flows to ensure sufficient and healthy food supplies amidst growing demand and climate change challenges.

Keywords: Climate change adaptation, crop productivity, food security, food system

Contact Address: Tony Carr, London School of Hygiene & Tropical Medicine, Department of Population Health, Keppel st, WC1E 7HT London, United Kingdom, e-mail: tony.carr@lshtm.ac.uk

Water management practices and adaptation to climate change: Cocoa farmers perceptions in Alto Beni, Bolivia

Melissa Morcote Martinez[1], Marc Cotter[2], Christine Bosch[1], Athena Birkenberg[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*Research Inst. of Organic Agriculture (FiBL), International Coop., Switzerland*

Cocoa is mainly managed by smallholder farmers in the tropics and constitutes one of the most important export commodities, being an important source of income. Lately, conventional cocoa monoculture has been promoted to achieve high short-term productivity at the expense of deforestation. However, such systems have negatively affected the water cycle with more intense heavy rains and longer drought periods, which is threatening food security and human welfare. In that sense, the perception that farmers have on climate change is determinant to the adoption and implementation of adaptation measures and policies in agriculture.

Thus, it is imperative a more agroecological approach to answer the question whether and to what extent cocoa farmers perceive and adapt their farming practices to the climatic variations, in conjunction with water use estimations of cocoa systems under different management. As such, the present study includes an analysis of farming practices' adaptations to climate change and a comparison of evapotranspiration in cocoa cultivation under different management.

In Bolivia, traditional cocoa production systems include shade trees. Particularly, cocoa agroforestry systems managed organically have proven to have smaller water footprint and are considered an effective nature-based solution to address climate change, biodiversity loss, food insecurity and rural poverty among other environmental and social challenges of this value chain. This study sought to assess evapotranspiration as a measure of water use in conventional monocultures and organic agroforestry systems in a long-term field trial in tropical Bolivia. In addition, to assess water and climate change-related management issues and their impacts on local rural livelihoods, farmers were interviewed to assess their perception of climate change, the adaptation of farming practices and water management related knowledge.

The results provide a joint assessment of the water use, key characteristics and, potential challenges of different management for cocoa cultivation in the context of water-related climate change. The socio-economic profile of farmers as well as the characteristics of the cocoa farms are described. Furthermore, on farm activities related to water management, a comparison among farmers' perceptions on the current climatic picture and the use of weather forecast tools among other adaptations are presented.

Keywords: Adaption to climate change, agroforestry, Bolivia, cocoa, farmers' perceptions

Contact Address: Melissa Morcote Martinez, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: melissa.morcotemartinez@uni-hohenheim.de

Greenhouse gas mitigation and soil carbon sequestration practices in the sheep sector

Nina Grassnick

Thuenen Institute, Coordination Unit Climate and Soil, Germany

Greenhouse gas (GHG) emissions from sheep production contribute eight per cent to global GHG emissions from the livestock sector. In some countries, GHG emission intensity from sheep meat production even accounts for the highest share of the country's GHG emission intensity from the livestock sector. However, little is known about current GHG mitigation and soil organic carbon (SOC) sequestration practices in the sheep sector. Therefore, this study aims on identifying policies and actors promoting these practices as well as what kind of practices are adopted, including adoption barriers. Data were collected in 2022 through a survey of 16 agricultural economic experts from 12 countries (Algeria, Argentina, Australia, Canada, Colombia, France, Germany, India, Iran, Peru, Spain and Tunisia). The results reveal that governments in 11 out of 12 countries have implemented at least one policy instrument to promote GHG mitigation and SOC sequestration practices with relevance for sheep production. These are often soft policy instruments such as research and development and/or farmers' training. Research bodies and independent farm advisors are the non-governmental stakeholders that are most active in promoting these practices. On average, farmers in the selected countries are likely to adopt animal management practices or practices that enhance productivity to reduce GHG emissions. The practices that are most likely to be adopted by farmers are feeding a diet balanced in energy and protein, increasing diet digestibility, increasing the lamb growth rate for earlier finishing and improving ewe nutrition in late gestation. However, the adoption of soil and pasture management practices to reduce GHG emissions or enhance SOC is less likely. This is especially the case for practices related to pasture renovation and plant selection, land use change, fertiliser and nutrient management or soil moisture. Avoid conversion of peatlands is the practice that has been selected most often to be unlikely adopted by farmers. The adoption of practices that enhance productivity is mainly prevented by economic barriers (e.g. uncertain returns and results as well as hidden costs). Behavioural/ psychological barriers are the main reason for the non-adoption of soil and pasture as well as animal management (e.g. conflict with traditional methods) practices.

Keywords: Adoption barriers, adoption of GHG mitigation practices

Contact Address: Nina Grassnick, Thuenen Institute, Coordination Unit Climate and Soil, Bundesallee 49, 38116 Braunschweig, Germany, e-mail: nina.grassnick@thuenen.de

Positive deviance in adaptation to climate change with sheep fattening: New pathways for farmer-led extension in Ethiopia

Birgit Habermann[1], Tigist Worku[2], Shenkute Goshme[3], Todd Crane[1], Elizabeth Getahun Tadesse[2]

[1]*International Livestock Research Institute (ILRI), Sustainable Livestock Syst., Kenya*
[2]*International Livestock Research Institute (ILRI), Sustainable Livestock Syst., Ethiopia*
[3]*Amhara Region Agricultural Research Institute, Debre Birhan Agricultural Research Centre, Dept. of Animal Breeding and Genetics, Ethiopia*

Farmers in the Ethiopian Highlands experience severe impact of climate change in terms of frost, hail and a shift in seasonality and rainfall patterns and intensity. Crop farming as a source of income has therefore become unreliable and some farmers focus on creating short-term incomes with small investment in livestock as replacement. We used the positive deviance approach as a conceptual framework. We started with an original sample of 34 local innovators that were selected in a qualitative research process. Consequently, we focused on four pioneer farmers for piloting an in-depth survey over more than a year in 2021 to 2022. The data collection involved repeated semi-structured interviews, monthly on farm visits during the implementation of modern sheep fattening, collecting data records on amongst others weight changes and feed. Participatory data collection is a learning process, and pioneers quickly adapted new approaches. We observed that the pioneer farmers were improving their practices over the short period of time we did this research together; that they openly engaged with others regarding this and adopted other farmers' recommendations easily – and vice versa; and that they even changed their self-perception from being an 'ordinary' farmer to someone who can become a community facilitator in farmer-to-farmer learning. We conclude that while we still have to learn more about how to partner with pioneers of adaptation in an on-farm scaling mechanism on climate-smart technologies, we see already now a promising reframing of how we can work with farmers. Climate change has a big impact on the farming systems at such high altitudes. To respond to the fast pace of these changes, we have to adapt the way we work with farmers: rather than focusing on mere adoption, we have to understand how farmers are implementing technologies already existing in their communities. While we still have to understand the challenges they are facing, we have to focus more on the solutions they are finding and develop technologies together with them starting from there.

Keywords: Adaptation, climate change, participatory action research

Contact Address: Birgit Habermann, International Livestock Research Institute (ILRI), Sustainable Livestock Syst., Nairobi, Kenya, e-mail: b.habermann@cgiar.org

Screening of sorghum hybrids for carbon sequestration potential under optimum irrigation and drought stress

Amna Eltigani, Lorenz Kottmann

Julius Kuehn Institute (JKI), Inst. for Crop and Soil Science, Germany

A significant amount of soil C can be captured by agricultural ecosystems through plant roots and harvest residues (humus formation). Crops characterised by large and deep root system such as sorghum (*Sorghum bicolor* L.), has high soil C input. Sorghum cultivation can contribute to improving soil organic C, therefore, climate protection. In Germany, the cultivation of sorghum is limited despite its suitability and competitiveness with other C4 crops such as maize. Moreover, sorghum cultivation in Germany is expected to increase under future climate scenarios of recurrent heat and drought events. In Germany, little is known about sorghum genotypes that are suitable for the local conditions. In this project, we will screen 10 sorghum hybrids for their biomass production and potential for C sequestration under drought stress in Braunschweig, Lower Saxony.

Sorghum phenotyping for biomass production and potential for C sequestration will be conducted under optimum irrigation and drought stress conditions. Ten sorghum test hybrids in addition to commercial sorghum and maize cultivars used as references will be screened under laboratory, greenhouse, and field conditions. We will assess crop phenological, morphological, and agronomic parameters. Furthermore, we will perform root sampling, as well as chemical analysis of plant tissues.

We expect that the sorghum hybrids will show various phenotypes and consequently various potentials for biomass production and soil C input under both optimum irrigation and drought stress conditions. Our results are expected to identify sorghum hybrids that are suitable for cultivation in German light soils susceptible to drought such as those present in Braunschweig.

Keywords: Above-and belowground biomass, cultivation, hybrids, root system, soil carbon sequestration, soil organic carbon, sorghum

Contact Address: Amna Eltigani, Julius Kuehn Institute (JKI), Inst. for Crop and Soil Science, Bundesallee 58, 38116 Braunschweig, Germany, e-mail: amna.eltigani@julius-kuehn.de

Impact of climate change adaptation strategies on net farm income of smallholder maize farmers in South Africa

Abeeb Omotoso[1], Chris Tshwene[1], Simon Letsoalo[1], Abiodun Olusola Omotayo[2]

[1]*North West University, Agricultural Economics and Extension, South Africa*
[2]*North West University, Food Security and Safety Focus Area Res. Group, South Africa*

The consequence of climate change on agricultural productivity relies on several interacting factors such as the timing of extreme weather events and rainfall which are predicted to become more recurring in the future. The study examined the determinants of climate change adaptation strategies (CCAS) and their intensity of adoption on the net farm income of smallholder maize farmers in South Africa. A multi-stage sampling technique was used to select smallholder maize farmers across thirty (30) villages in North West province, South Africa. The data were analysed through descriptive and inferential statistics - endogenous switching regression model, multivariate probit regression (MVP) and negative binomial regression model (NBRM). The results of the descriptive statistics revealed that the majority (78.0 %) of the household-head were married, while their mean household size, farm size, and age were 6 persons, 4.2 hectares, and 47.2 years, respectively. The parameter estimates of the MVP model revealed that the coefficient of age of the respondents, household size, years of farming experience, off-farm income, and access to credit significantly influence the choice of CCAS adopted. Additionally, gender of the household, main occupation, farm size and access to climate information were the significant factors influencing the adoption intensity of CCAS among the smallholder farmers in South Africa. This research concluded that mixed cropping, crop rotation, mulching and agroforestry were the major CCAS adopted by the smallholder maize farmers in South Africa while the educational status of the household head, access to credit, farm size and off-farm income are significant in explaining the variations in the net farm income of both adopter and non-adopter of CCAS. Therefore, the research recommends that government should strengthen public agricultural credit services, enhance extension services, provide on-farm demonstration training, and disseminate information about CCAS as this will facilitate the adoption of climate-smart farming practices by farmers particularly for smallholder farmers in South Africa in their effort to deal with climate change.

Keywords: Climate adaptation, climate-smart farming, multivariate probit regression, negative binomial regression

Contact Address: Abeeb Omotoso, North West University, Agricultural Economics and Extension, Mmbatho, Mafikeng, South Africa, e-mail: omotosoabeebtunde@yahoo.com

(Agro)forestry and (agro)biodiversity

Agrobiodiversity and (agro)forestry to transform food systems

Online posters

Mainstreaming agrobiodiversity for enhancing climate resilience, nutrition, and livelihoods

Jai C. Rana[1], Rashmi Yadav[2], Sarika Mittra[1], Sonal Dsouza[1]

[1]*The Alliance of Bioversity International and CIAT, India*

[2]*ICAR - National Bureau of Plant Genetic Resources, Div. of Germplasm Evaluation, India*

Continuous cultivation of a few dominant crops and varieties has eroded native crops diversity, environmental sustainability of food production, increased pest risks, etc. Declining crops and varietal diversity, narrow dietary system have led to malnutrition, and climate risks. These system shocks generally affect the marginalised fractions in society disproportionately and increase social inequality. Rural households, resource poor communities and vulnerable groups such as women and the youth bear the effects heavily as they lack resources to support rapid lifestyle adjustments. We are implementing a UN Environment-GEF funded project in India and aiming to mainstream native agrobiodiversity and improving their seed systems through community seed banks and linking those production systems to various market channels. Under the project, farmers are being empowered to exercise control over their plant genetic resources – expressed as local crop varieties, a major asset, and to use this to improve their livelihoods through better farming practices, and aligning market, societal and conservation goals in product value chains. To enhance genetic diversity on farm, 4278 native varieties of 20 crops were tested in 759 participatory variety selection (mother) trials and 5028 baby trials were tested and farmers identified 233 varieties of different crops as the most potential varieties suitable to their diverse needs. We also repatriated >3500 accession form national gene bank to farms from where they had collected but were lost overtime. Seed system strengthened with 29 community seed banks at 17 project sites, conserving >3000 native varieties. For adopting best practices at community level several farmers have been trained and designated as champion farmers working closely with >150 self help groups (SHGs), 25 farmers' producer groups and private companies on value addition and product development for improved adaptation and livelihoods. To generate awareness and to enhance farmers' skill on agrobiodiversity conservation and use we conducted >600 trainings, awareness workshops, field days, cross learning exposure visits. To provide linkage to agrobiodiversity 06 value chains have been developed through in-depth nutritional profiling, branding, packaging, and labelling. This has improved framers' livelihoods significantly.

Keywords: Climate, mainstreaming agrobiodiversity, nutrition, value chain

Development of agroforestry in upland northern Vietnam: A farmers' perspective

Hoa Do[1], Cory Whitney[1], Nguyen La[2], Eike Luedeling[1]

[1]University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany
[2]World Agroforestry, CIFOR-ICRAF, World Agroforestry, Kenya

Fruit tree-based agroforestry has been promoted as an alternative farming practice in upland Northwest Vietnam, which may replace erosion-prone staple crop monocultures. Although many studies have focused on evaluating the performance of agroforestry systems at the plot level, there has been little research on how farmers perceive and evaluate agroforestry and how adoption barriers may be overcome. We combined the Q method, which aims to explore commonalities and differences in farmer perspectives (discourses), with system thinking to understand farmers' decision-making processes within the adoption context. Through the Q method, we identified three different discourses among agroforestry farmers on the farm-level impacts of adoption. Two of the three discourses are in favour of agroforestry, highlighting its beneficial impacts on livelihoods and environment, through diversification of household income and soil erosion control. The disagreement in farmer perceptions reflected the diversity of farmers' experiences and adoption management strategies. We also generated a collective development pathway where farmers navigated and adapted the agroforestry practices to overcome adoption challenges. To illustrate these pathways, we used system thinking to visualise farmers' mental models, which reflected a whole-system approach to farm resource management. Farmers leveraged the beneficial impacts of agroforestry and adaptively managed challenges, drawing upon systemic understandings of trade-offs and synergies. We identified structural barriers, such as unstable farm-gate prices, that may need intervention at higher levels. In addition to technical and financial support, a proper integration of informal and formal social networks in local agroforestry innovation systems may promote effective learning and cooperation to overcome both field-level and structural challenges. System thinking and its outcomes allow for social learning and assist researchers and policymakers in designing research and support mechanisms. While our study focused on the development of agroforestry, the approaches could be adapted to study a wide range of other agricultural innovation systems.

Keywords: Agroforestry, farmer perception, Q methodology

Contact Address: Hoa Do, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Science, Auf dem hügel 6, 53121 Bonn, Germany, e-mail: dohoa1190@gmail.com

Diversity and diversification in cocoa agroforestry systems and household food security: Case study of central and southeastern Côte d'Ivoire

Constant Yves Adou Yao[1], Venance-Pâques Gniayou Kouadio[1], Affia Sonmia Francia Kossonou[2], Bonna Antoinette Tokou[3], N'Gouan Emmanuel Joël Abrou[1], Bruno Kouassi Kpangui[2]

[1]University Félix Houphouët-Boigny, Côte d'Ivoire

[2]University Jean Lorougnon Guédé, Agroforestry, Côte d'Ivoire

[3]Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

Côte d'Ivoire is a country with a strong agricultural vocation. The world market is increasingly demanding beans from sustainable production systems, encouraging cultivation methods that are better adapted to climate change while contributing to the food security of local families. For resilient cocoa production, some farmers in Côte d'Ivoire have adopted agroforestry systems for several generations. To better appreciate the viability of these systems, this study proposed to analyse their diversification and diversity and their effects on the lives of households in two contrasting production zones of Côte d'Ivoire, and on their food security. The research implemented ethnobotanical and socioeconomic survey methods with 152 producers and 268 women involved in the production of products from cocoa-based agrosystems. It carried out botanical inventories and direct observations in 100 cocoa plantations. The data analysis showed that 30 % of women in the Center own a cocoa farm with a total of 79 companion plant species against 105 associated species associated in men's plantations. Among these, 28 species that produce fruits or seeds that are consumed directly by households or marketed and 38 species whose barks, leaves and roots are used in traditional medicine. In the Southeast, 117 companion species were inventoried with 48 species used (41 % species inventoried). They are used in several purposes. In addition, the study shows that in the Center, 12 % of households surveyed are food insecure. Less than 25 % of the populations assessed were heavily involved in survival, stress and crisis strategies at the time of the study. This work shows that the diversity of income sources increases with the complexity of the systems and contributes to the well-being of producers, hence the need to promote agroforestry in the current context of climate change and food security of vulnerable households.

Keywords: Agroforestry systems, Côte d'Ivoire, diversification, food security, uses, women

Incentivising the conservation of rare agrobiodiversity in Ethiopia

Sophie Jago[1], Adam Drucker[2], Bezawit Genanaw[3], Asaminew Woldgegebriel[4], Wendawek Abebe[3], James Borrell[1]

[1]*RBG Kew, Trait diversity and function, United Kingdom*
[2]*The Alliance of Bioversity International and CIAT, Effective Genetic Resources Conservation and Use, Italy*
[3]*Addis Ababa University, Plant Biology and Biodiversity Management, Ethiopia*
[4]*Mizan Tepi University, Ethiopia*

Agrobiodiversity is critical for human survival and wellbeing, yet is at risk of rapid and global decline. Maintaining agrobiodiversity generates private and public benefits, including climate resilience, food security and economic development opportunities. However, the costs of maintaining such public goods often fall on poor smallholder farmers who maintain crop genetic diversity on-farm in an ad-hoc manner based on their private preferences. A more strategic approach, which more fairly distributes these costs and benefits, is payments for agrobiodiversity conservation services (PACS). PACS draws upon concepts from payments for ecosystem services, which has been widely applied to multiple environmental sectors. PACS compensates farmers for opportunity costs incurred by maintaining rare crops for public good over those with higher private returns. Here, we report on a PACS scheme around Kafa Biosphere Reserve, Ethiopia, aiming to conserve rare landraces of the nationally important crop, enset (*Ensete ventricosum*). Enset, is a staple food for over 20 million Ethiopians and is characterised by hundreds of locally-adapted landraces. Surveying over 500 farmers (35 % women) from 22 communities using a four cell method, we identified 175 farmer-recognised landraces, 57 of which were rare and in need of conservation effort. All 22 communities submitted offers in a competitive tender for the conservation of these rare landraces. This yielded average cultivation costs of £2.16 per plant with different landraces ranging from £0.36 to £14.71. The cost variation may link to differing farmer preferences regarding landrace traits such as taste, growth rate, and drought or disease susceptibility. Seeking to address trade-offs between environmental (i.e., maximising landrace diversity) and social (i.e., maximising participation) outcomes, a linear programming model selected 44 landrace offers across 15 communities. We consequently demonstrate the ability to achieve significant landrace diversity conservation in a cost-effective, equitable and transparent manner. This approach has the potential to be scaled-up and applied across a wide range of crops, thereby delivering outputs relevant to global biodiversity framework targets and sustainable development goals through sustainable, *in situ* conservation of agrobiodiversity, contributions to food security and poverty reduction, and maintenance of traditional land management practices of local communities.

Contact Address: Sophie Jago, RBG Kew, Trait diversity and function, RBG Kew, TW9 3AB London, United Kingdom, e-mail: S.Jago@kew.org

Contribution of NTFP certification to smallholder forest livelihoods: A case from Kyzyl-Unkur village in walnut-fruit forests in Kyrgyzstan

Klara Dzhakypbekova[1], Dietrich Darr[2]

[1]*University of Bonn, Center for Development Research (ZEF), Germany*
[2]*Rhine-Waal University of Applied Sciences, Fac. of Life Sciences; Sustainable Food Systems Research Centre, Germany*

The walnut-fruit forests on the Ferghana and Chatkal mountain ranges in Kyrgyzstan are considered as a global biodiversity hotspot, they also have the soil-protection and water regulating functions, and are the major source of income to the local households. Collection of walnuts and other NTFPs in Kyrgyzstan constitute an important basis for the local livelihoods. Previous studies recommended that the logistical and infrastructural improvement of the existing value-chains in accordance with the international sustainability standards might positively change the socio-economic welfare of the local livelihoods, and promote sustainable forest management to reduce deforestation. The NGOs and donor programmes introduced the NTFP certification projects of the Fair Trade certification in 2008 and Forest Stewardship Council (FSC) NTFP certification in 2018 within the selected pilot communities of the walnut forests in Kyrgyzstan both aiming to improve the socio-economic welfare, sustainable forest utilisation and conservation of the walnut forests. However there is a limited understanding about the possible effects and impacts of these certification programmes on the local livelihoods and the socio-ecological situation in the local forests.

It is important to analyse the current state of the existing NTFP certification cases along with their success or failure factors, as well as other important contextual conditions. 510 households' socio-economic data was collected within five communities of the Kyzyl-Unkur village, located in walnut-fruit forests in Kyrgyzstan. The data collection was performed among the households who participated in NTFP-certification schemes and those who did not take part in these activities. A comparative socio-economic analysis was done in order to understand the contribution of the existing NTFP-certification schemes to the local livelihoods. Along with that the stakeholder and social-network analysis was applied in order to analyse the patterns of involvement of the local households in the NTFP-certification activities. The provided research results are used to describe further challenges and opportunities for the future of NTFP certification schemes in the country.

Keywords: Forest certification, non-timber forest products

Contact Address: Klara Dzhakypbekova, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: klara.dzhakypbekova@gmail.com

Analysis of social dynamics for the *in situ* maintenance of native potato agrobiodiversity in Paucartambo, Peru

Maria Cordero-Fernandez[1], Giovanna Chavez-Miguel[2], Michelle Chevelev-Bonatti[2]

[1]*Humboldt-Universität zu Berlin, Dept. of Agricultural Economics, Germany*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SUSLand), Germany*

Agrobiodiversity, a key component of sustainable food systems, is funded upon social interactions of farmers that allows their maintenance. The Andes, considered a hotspot of agrobiodiversity, is the centre of origin of a wide variety of potatoes and tubers, which are maintained *in situ* on the highlands by family farmers at a small-scale. Farmer-based agrobiodiversity maintenance offer potential for strengthening food security of rural populations, conserving the biocultural heritage, and ensuring the persistence of traditional farming livelihoods. The maintenance of agrobiodiversity on the Andes relies on social dynamics related to the exchange of intra-ecological products, knowledge, seeds, and to some extent, collective farming practices. This study investigates social dynamics related to agrobiodiversity management in Paucartambo - Cuzco, a region characterised by its high levels of varietal diversity, traditional communal farming practices, and its cosmovision. We apply methods from ethnography, including semi-structured interviews, focus groups and participants observation, as well as elements from visual anthropology, i.e., film-based interviews and workshops. Our results shown that ancestral communal dynamics are currently being replaced by individual practices due to the competitive logic of public incentives for conservation, affecting thereby the local social fabric and transforming the way agrobiodiversity is maintained. At the same time, the emergence of trans-local conservation networks, such as the Association of Native Potato Guardians of Peru (AGUAPAN), advance new organisational mechanisms aimed at strengthening regional farmer-based conservation networks by generating new spaces of convergence. By analysing how local actors coordinate efforts to maintain agrobiodiversity in the current context of socio-environmental transformation, we argue that emerging organisational mechanisms aimed at nurturing the social fabric are needed for agrobiodiversity maintenance. Based on farmer perceptions, we emphasise the need for proactive measures for supporting agrobiodiversity conservation and generate recommendations for fostering organisational and leadership capacities that help strengthen autonomy and self-governance of local organisations.

Keywords: Agrobiodiversity, farmer seed systems, social dynamics, social-ecological systems, traditional knowledge

Contact Address: Maria Cordero-Fernandez, Humboldt-Universität zu Berlin, Dept. of Agricultural Economics, Berlin, Germany, e-mail: mariajose.corfer@gmail.com

Does agroforestry affect human health and nutrition?

Julia Knollmann[1], Kati Krähnert[1], Amanda S. Wendt[1], Jillian Waid[1], Sven Bratschke[1], David Abigaba[1], Katja Kehlenbeck[2]

[1]*Potsdam Institute for Climate Impact Research, Research Dept. II: Climate Resilience, Germany*
[2]*Charité - Universitätsmedizin Berlin, Institute of Public Health, Germany*

Agroforestry - the integration of woody plants into crop or livestock management - is regarded as a sustainable agroecological production method that contributes to numerous aspects of planetary health, including environmental health and human well-being. While considerable literature is available on the benefits of agroforestry on soil fertility, climate change mitigation and the economy of local communities, the impact of agroforestry on human nutrition and health is less often researched or included as an explicit objective in agroforestry programs. Closing this potential knowledge gap on the direct impacts of woody plants in agroforestry systems on human health and nutrition could help to create awareness among stakeholders involved in agroforestry programmes and lead to increased integration of nutrition and health aspects into future agroforestry programs. To assess the extent of the postulated knowledge gap, the present study is reviewing the existing evidence of the links between woody plants in agroforestry systems to human health and nutrition.

In this systematic review, scientific literature is examined in terms of content, whether direct impacts of woody plants in agroforestry systems on human health and nutrition are assessed by qualitative or quantitative methods. Included direct impact categories are human nutrition, medicine from woody plants, infectious diseases, mental health, microclimate and air quality. We searched four bibliographic databases, namely PubMed, AGRIS, Web of Science and Scopus, including all languages and study designs, covering all time periods until January 2023. Experts from different organisations and disciplines will also be interviewed to include information from grey literature such as project reports.

Our search returned 7460 citations of which we included 335 articles after screening titles and abstracts. Most of the included studies refer to the impact categories nutrition and medicine, whereas mental health and air quality are least represented. However, the direct links to human health and dietary intake might be missing in some of these publications. The next steps are full-text review and final selection of papers for data synthesis. This study is still on-going and final results will be presented at the conference.

Keywords: Medicine from woody plants, mental health, microclimate, nutritional security, woody plants

Contact Address: Julia Knollmann, Potsdam Institute for Climate Impact Research, Research Dept. II: Climate Resilience, 14412 Potsdam, Germany, e-mail: julia.knollmann@pik-potsdam.de

ID 795

Does training in dynamic agroforestry change doing, organising, meaning, and knowing in smallholder systems in Bolivia?

Julia Männle[1], Johanna Rüegg[2], Joachim Milz[3], Lorenz Probst[1]

[1]*University of Natural Resources and Life Sciences (BOKU), Dept. of Sustainable Agricultural Systems, Austria*
[2]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*
[3]*Ecotop Foundation, Bolivia*

Bolivia is among the countries with the highest deforestation rates in Latin America due to the expansion of commercial agriculture, timber production, and mining activities. At the same time, smallholder farmers face challenges such as the impacts of climate change, soil degradation, and unstable market prices. Local and international actors have promoted dynamic agroforestry (DAF) as an approach to improve living conditions, restore natural habitats and increase adaptive capacity for over two decades. Currently, stakeholders involved in promoting DAF in the Alto Beni region of Bolivia seek to understand better how the approach has integrated with and potentially changed local socio-ecological realities. Accordingly, our goal was to explore whether DAF training and the possible implementation of DAF have contributed to new ways of doing, knowing, meaning, and organising in smallholder agroecosystems in the study area. We draw on relational concepts, including nonhuman agency and the emphasis on dynamics and processes, to frame our research interest. We used participant observation, interviews, narrative walks, and a mapping exercise to address the research question with twenty farmers and other stakeholders in the region. Preliminary results indicate that participating in the DAF training has indeed created space for exchange, reconsideration, and re-strengthening of social-ecological relations. By engaging more deeply with the roles and needs of flora, fauna and soil, feelings of kinship were rekindled, according to participants. We suggest that this perception shift towards reciprocity and care will play a major role in initiating long-term changes in farming practices. The participants also attempted to raise awareness and encourage their family and community members to cease practicing shifting cultivation and to diversify their production systems. Ongoing follow-up activities and consistent communication with promoting organisations will be essential for maintaining the relationships established through the training and for ensuring the continuation of the newly implemented agroforestry systems.

Keywords: Agroforestry, Bolivia, change processes, relationality

Contact Address: Julia Männle, University of Natural Resources and Life Sciences (BOKU), Dept. of Sustainable Agricultural Systems, 1190 Vienna, Austria, e-mail: jmaennle@students.boku.ac.at

Assessing the relevance of traditional market channels for potato diversity on the Peruvian Andes

Janika Hämmerle[1], Giovanna Chavez-Miguel[2], Stef de Haan[3], Stefan Sieber[2]

[1]*Humboldt-Universität zu Berlin, Dept. of Geography, Germany*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SUSLand), Germany*
[3]*International Potato Center (CIP), Andean Initiative, Peru*

In the Peruvian Andes, family farmers maintain over 3.000 potato varieties on their farms. Although the motivations for conserving varieties are mainly cultural, they are also economically driven. The persistence of agrobiodiversity relies on the ability of farmers to secure their livelihoods through the commercialisation of their produce. Located in remote and poorly connected areas, potato farmers must travel long distances and pay high transport costs to commercialise their produce. In this context, local markets held weekly in villages, represent the main market channel for family farmers and often their only source of income. This study assesses the relevance of traditional markets for potato diversity and identifies which market channels absorb greater levels of family farmers' agrobiodiversity. By applying an inductive quantitative research approach, we carry out a cross-case comparison of local and regional markets (n=35) located across 9 study areas along the traditional Andean road network, the Qhapaq Ñan. Through a diversity analysis, we quantify market-linked varieties based on richness, uniqueness, evenness, and Shannon-Weaver indexes. Drivers influencing the occurrence of agrobiodiversity at the different market channels are identified by means of a multiple linear regression analysis. In total, we recorded 150 potato varieties across all markets, 61 of them as unique varieties, ranging from 2 to a maximum of 35 varieties per market. Higher levels of diversity were recorded at regional and local markets involving predominantly local producers, displaying thereby associative processes and a stronger social fabric. Lower diversity was observed at local markets with an increasing tendency of urbanisation and at small local markets located in potato production hotspots. Our results demonstrate that the market-linkage of agrobiodiversity is mainly determined by spatial factors, as well as aspects related to accessibility, consumer awareness, and fair pricing. Market-based organisational processes are key for enabling a fair retribution for producers. Although market linkage is crucial for sustaining farmers' livelihoods, the occurrence of native potatoes at markets remains marginal, contrasted to the modern potato varieties that dominate the markets. We emphasise the need to strengthen market-linkage of family farmers' produce by fostering associativity processes within the existing network of localised markets.

Keywords: Agrobiodiversity, family farming, farmer markets, local food systems

Contact Address: Janika Hämmerle, Humboldt-Universität zu Berlin, Dept. of Geography, Herbststraße 18, 13409 Berlin, Germany, e-mail: haemmerj@hu-berlin.de

Land cover changes and natural vegetation dynamics in northern Niger (1955–2023)

Kira Fastner[1], Hamza Guerbaoui[2], Thanh Thi Nguyen[1], Youness Boubou[1], Martin Wiehle[1], Lamiae Ghaouti[2], Andreas Buerkert[1]

[1]*University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany*
[2]*IAV Hassan II, Production, Protection and Plant Biotechnology, Morocco*

Past and current knowledge about natural vegetation and land cover dynamics in the mountains of the Saharan Desert is largely limited, although these regions provide habitats for diverse taxa and livelihood options for humans and are considered stepping stones between northern and central African ecosystems. This study will focus on the Aïr Mountains of northern Niger as largely pristine socio-ecological systems. The region is inhabited by Touareg people, nowadays practicing irrigated oasis agriculture combined with sheep and goat pastoralism on sparse pasture land. Population pressure, accompanied by increasing livestock stocking rates and recurring drought conditions, affect vegetation patterns and biomass production in the region. Moreover, telecoupled urban demands of sprawling West African cities has led to an expansion of irrigated agriculture for cash-crop production. This has resulted in extensive land clearing and falling groundwater tables, potentially causing negative effects on pastures, wild plants, local varieties, and overall biodiversity.

Through GIS-based mapping of agriculture and natural vegetation based on aerial photographs, Sentinel and Landsat images as well as drone-based surveys, this study aims at quantifying land cover changes from 1955 to 2023 in Timia, Mont Bagzam and their surroundings. Normalized difference vegetation index (NDVI) analyses were carried out and matched with manual and supervised land use and land cover (LULC) classifications of shrubs/trees, agricultural land, natural grassland and barren land. Seasonal herding activities were recorded with GPS loggers for 2021 to 2023 to identify possible grazing effects on land cover changes. Records over the past 10 years of sheep and goat sales to the biggest nearby marketplace of Agadez were analysed for changes in production amounts.

Keywords: Agro-pastoral systems, mountain habitats, rangelands, telecoupling

Contact Address: Kira Fastner, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: kira.fastner@uni-kassel.de

The effects of cocoa production and consumption on biodiversity loss and ecosystem services

Patrick Opoku

Kwame Nkrumah University of Science and Technology, Forest Resources Technology (DFRT), Ghana

The economy of many countries depends heavily on cocoa production and trade. According to the Netherlands Ministry of Foreign Affairs, Europe is the largest importer of cocoa beans in the world and Germans are the largest chocolate consumers in the world with a per capita consumption of 11 kg per year. Switzerland is ranked as the second largest with 9.7 kg per capita, followed by Estonia with 8.8 kg. Over the years, West Africa has been the main supplier of cocoa beans to Europe. Unfortunately, however, in recent times, there has been an assault on forest reserves for cocoa plantations. There has also been a shift from 'shade cocoa' to 'sun cocoa'. These practices are putting additional stress on biodiversity conservation and ecosystem services. This study reveals a pronounced trade-off between short-term cocoa productivity and ecosystem health as well as biodiversity, and shows that the higher yielding short cycle hybrid cocoa varieties grown under full sun or minimal shade exhaust soil nutrients and degrade the ecosystem so that it becomes unsuitable for further cocoa farming or other productive agriculture and biodiversity conservation. While consumers are growing more conscious of the importance of biodiversity, most of them are still uninformed of the connection between their consumption habits and the factors causing the loss of biodiversity and ecosystem services. This study bridges this knowledge gap. The study uses Ghana as a case study to answer the following questions: (i) What do sustainable cocoa production look like from a natural resource perspective? (ii) How can resource efficiency in cocoa production be improved to enhance food security? (iii) How can the transition to sustainable cocoa production be managed? The study provides findings on cocoa farming in the context of sustainable production and consumption. Strategies and best practices for cocoa production are discussed.

Keywords: Biodiversity loss and ecosystem services, cocoa production, consumption

Contact Address: Patrick Opoku, Kwame Nkrumah University of Science and Technology, Forest Resources Technology (DFRT), P.O. Box up 98, Kumasi, Ghana, e-mail: opoku_patrick@yahoo.com

Understanding the relevance of traditional market networks for local economies and agrobiodiversity on the Peruvian Andes

Giovanna Chavez-Miguel[1], Janika Hämmerle[2], Stef de Haan[3], Stefan Sieber[1], Michelle Chevelev-Bonatti[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SUSLand), Germany*
[2]*Humboldt-Universität zu Berlin, Dept. of Geography, Germany*
[3]*International Potato Center (CIP), Andean Initiative, Peru*

In face of the urgent need for more sustainable food systems, enabling the provision of diverse foods supplied locally by family farmers is crucial. In this context, local markets are essential spaces for family farmers' economies and key access points for agrobiodiversity. The Peruvian Andes host an ancestral road and market network, the Qhapaq Ñan, that constitute an intra-ecological trade route, in which the exchange of family farmers' agrobiodiversity from diverse geographies occurs. This study proposes a methodological framework for investigating the relevance of traditional market networks funded upon mixed quantitative, qualitative, and cartographic methods. By applying an inductive multi-stepped research approach, we carry out a cross-case comparison of local and regional markets (n=35) located across 11 study regions of the Peruvian Andes. Our results present a market characterisation funded upon geographical-spatial data, estimation of produce shares, produce flows maps, an actor typology, and an agrobiodiversity assessment. Based on this, we identify which of these market types absorb greater levels of family farmers' agrobiodiversity, the socio-cultural functions of markets that support the social fabric, as well as the attributes of markets that go in line with the ecological rationality of family agriculture. Based on our results, we argue that the relevance of traditional market networks lies in their potential to dynamize local economies and enable the persistence of family farmers' agrobiodiversity, if strengthened. We emphasise the need for more proactive policies aimed at promoting localised food provisioning stemming from family agriculture and the strengthening of existing agroecological and traditional market networks.

Keywords: Local food systems, social learning, socio-ecological systems

Farmer's seed diversity and seed conservation practices in Nakuru Kenya

Lorenz Bachmann[1], Johannes Kotschi[1], Dominic Kimani[2]

[1]*Agrecol Association, Germany*
[2]*Seed Savers Network Association Kenya, Kenya*

Farm-saved seed is existential for agriculture and nutrition in Kenya. For many crops families still depend almost entirely on breeding and seed conservation. A survey with 244 farmers, predominantly female (68 %) was used as a baseline to understand farmers practices. Farms are very small (0,6 ha median) with only 0,17 ha per household member. Farmers are cultivating on average 17 crops, and in the order of importance these are maize, Irish potatoes, kales, spinach, wairimu bean, spring onions, kifamu bean, garden peas, black nightshade, kahurua bean, pumpkin, sweet potatoes, witemania bean, Amaranth, coriander, yellow bean, broad bean, spider weed, tomato and Comfrey. The land shortage and climate change risks make farmers focus on many different bean varieties (16) and various vegetables (13) besides tuber crops (5) to secure their food security. While the number of crop species cultivated per farm was high, intra-species diversity was rather limited. Most farmers only grow one variety per crop, and rarely two. Overall, the survey identified 3–4 varieties for most species, For 2 out of 40 species researched, a high number of 8 varieties were mentioned during the interviews. This highlights that's biodiversity loss is a major threat for Kenya. To assist in this fight against biodiversity loss, Seed Savers Network Kenya together with Agrecol introduced a commons-based process of describing and documenting local varieties. This approach is intended to improve farmers' seed supply and provide some protection against private appropriation. The results of this work will be forthcoming in the next years. For their seed needs, farmers still depend largely on their own production or neighbours in their community. So far, seed banks only play a minor role. The self-sufficiency of farmers for seed is very good and for most beans it reaches up to 100 %. But even for vegetables with temperate origin that are more difficult to maintain for seed, some 30–40 % of farmer manage to keep their own seeds.

Keywords: Agrobiodiversity, farmers' varieties, food security, open source seeds, traditional seed

Agroforestery and permaculture for sustainable development of human and nature

Asmelash Dagne Datiko

Gardula Peoples Developemnt Assosation, Agroforestry and Permaculture, Ethiopia

The ever-changing and unpredictable climate is affecting most of the small-holding farmers in sub-Shaman Africa. To develop reliance and enhance adaption to climate change an integrated natural resource management approach with the framework of Agroforestry and Permaculture will enhance the sustainable and resilient livelihood for the small holding farmers.

Agroforestry is a dynamic, ecologically based natural resources management system that promotes the integration of trees in farmland and rangeland. It also promotes biodiversity to ensure sustainability, productivity, profitability, health and sustainable land-use systems to create socially, economically, and environmentally sustainable communities at each level. Permaculture is also a harmonious integration of landscape and people, providing their food, energy, shelter and other material and non-material needs in a sustainable way to maintain stable social order. Integrating the two concepts will enhance the sustainable development of humans and nature.

Teaching the local farming community to adapt to an integrated resource management approach is a long process and they learn through observation. Accelerating the adaptation by smallholding farmers upgrading the existing infrastructure (Farmer training centre) to perfect demonstration sites through the farmer-based initiative is the way forward to reach as many as possible farmers to build resilience to the ever-changing climate.

In the southern region of Ethiopia, the local development association is working with its local and international partners to train 7,000 farmers to adopt sustainable natural resources management through practicing agroforestry and Permaculture. The approach is to address the local farmers and convince them to adopt the resilient through regenerating the entire ecosystem. The project is enabling the farmers and extension workers to transform the farmer training centre to a more productive and resilient ecosystem where the farmers can learn through observation and adapt.

We are very happy to share our experience, success, challenges and ways forward at the Tropentag 2023.

Keywords: Agroforestery, green energy and food, integrated natural resource management, sustainable development

Contact Address: Asmelash Dagne Datiko, Gardula Peoples Developemnt Assosation, Agroforestry and Permaculture, Muluwongel sefer 23, 1002 Arba minch, Ethiopia, e-mail: dassc.asmelash@gmail.com

Sustainable livelihoods in protected areas: The case of *Pimenta dioica* in the Maya biosphere reserve

Andrés Charry, Luisa Claros, Jenny Wiegel

The Alliance of Bioversity International and CIAT, Colombia

The Maya Biosphere Reserve (MBR) in Petén, Guatemala has been a successful model for community-managed forests in Central America since 1990, with *Pimenta dioica* gaining significance due to its increasing demand. This study examined the value chain of *P. dioica* in Guatemala, with a specific focus on the MBR, identifying the main actors, activities, trade flows, price points, margins, markets, trends, challenges, and opportunities for sustainable harvesting and marketing of this valuable resource. The study used a literature review, semi-structured interviews with key informants along the value chain, and focus group discussions with community representatives and harvesters. Our findings revealed that harvesting *P. dioica* is a high-priority activity for forest communities due to its relatively high price and income generation potential, and the participation of women and youth in various activities along the value chain. However, changes in climatic conditions have severely affected the harvesting seasons, threatening a consistent supply. Moreover, local cooperatives and intermediaries compete for local production, capturing different shares of added value depending on the product characteristics, certifications, and distance of the communities. The fruit is mainly exported dried, channeled by a limited number of actors mainly towards the USA and EU where it can reach retail prices between 7 to 26 times greater than the export price. The study identifies several opportunities for value chain strengthening, including forest enrichment, grafting, drying facilities, and product differentiation based on organic, fair, and sustainable production for forest conservation. However, increased bargaining power from producing countries and increased consumer information are necessary to achieve a more equitable value distribution. In conclusion, our study provides insights into the value chain of *P. dioica* in the MBR, highlighting the importance of community management and sustainable harvesting practices. It also identifies several opportunities for value chain strengthening, which can enhance the economic benefits for the local communities and promote forest conservation. Nonetheless, challenges such as climate change and unequal value distribution remain significant obstacles to overcome. Further research is necessary to develop effective strategies for the sustainable management of *P. dioica* and other forest products in the MBR and similar contexts.

Keywords: Community managed forests, forest conservation, non timber forest products, value chain analysis

Contact Address: Andrés Charry, The Alliance of Bioversity International and CIAT, Km 17 recta Cali - Palmira, Cali, Colombia, e-mail: a.charry@cgiar.org

Uses of *Hyphaene* species known as mikoche and consumption constraints as food in Tanzania

Amina Ahmed, Leonard Fweja, Happy Magoha

Mbeya University of Science and Technology, Dept. of Food Science and Technology, Tanzania

Hyphaene, commonly referred to as *mkoche* (plural *mikoche*) in Swahili, belongs to the Palmae (Arecaceae) family and is found in the coastal regions of Tanzania. The tree is used as a construction material for shelter, and its leaves are used to make woven products such as baskets, mats, and hats due to their strength and fibre length. In addition, the fruit of the *Hyphaene* tree is a good source of fibre, antioxidants, B-complex vitamins, essential minerals, monosaccharides, essential oil, and flavonoids, which are important compounds for human nutrition and health. Furthermore, *H. coriacea* produces edible nuts and palm wine in Maputaland coastal plains in KwaZulu-Natal, South Africa, and *H. coriacea* is known to produce edible oil from its nuts. However, despite its widespread presence, the economic potential of *mikoche* in Tanzania has yet to be fully unlocked. Therefore, a field survey will be conducted in the Pangani District in Tanga Region, Tanzania, to find and link the first-hand knowledge about the possibilities and constraints in producing, processing and utilising *mikoche* as a food source. The generalised linear model (GLM) and chi-square test will be used to predict the constraints of the production and processing of the *mikoche* in the Tanga region. Therefore, this study will highlight the need to invest in research and development towards innovative ways to exploit the economic potential of *mikoche* in Tanzania to sustain climate change and the growing demand for resource diversity, food and nutrition security. Moreover, documenting the uses and consumption constraints will help understand the natural resources systems, including product development for alternative food sources.

Keywords: Climate change, consumption constraints, food and nutrition security, *Hyphaene* species, natural resources

Contact Address: Amina Ahmed, Mbeya University of Science and Technology, Department of Food Science and Technology, 131 Mbeya, Tanzania, e-mail: mimomed88@gmail.com

Agrobiodiversity maintenance through everyday practices: A gender-analysis of women's role in native potato conservation

Imke Scheepstra[1], Giovanna Chavez-Miguel[2]

[1]*Freie Universität Berlin, Inst. for Latin American Studies (LAI), Germany*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SUSLand), Germany*

Agrobiodiversity systems are mainly maintained by family farmers, who hold vast knowledge around the cultivation and use of diverse crops. Agrobiodiversity maintenance is a complex process, which involves environmental, cultural, and economic factors, social relations, institutions, and knowledge systems.

The knowledge and practices of women in particular, play a key role in family agriculture and in agrobiodiversity maintenance.

This qualitative study investigates the role of women in the maintenance of agrobiodiversity through the observation of everyday life. We focus on potato diversity, native to the Peruvian Andes, which is conserved *in situ* by family farmers. By applying ethnographic field methods, including semi structured interviews and film-based interactions, we analyse the different dimensions of agrobiodiversity maintenance, identify women's vulnerabilities and their daily life strategies of persistence. We look at women's specific knowledge and everyday practices that are essential for sustaining socio-ecological relationships, from a gender sensitive, intersectional, and power critical perspective.

Our results show how the farm and care work of women, and in particular their everyday food provisioning practices, contribute to agrobiodiversity maintenance. Women's knowledge on seed selection, agroecological cultivation, environmental care, marketing, and their awareness about family nutrition combined, are sustaining force for agrobiodiversity. Based on our results, we argue that women's everyday practices contribute to food sovereignty and can be understood as strategies of persistence in a context of global socioecological transformations. We emphasise the need to acknowledge the value of traditional knowledge systems and especially the role of women farmers in keeping these knowledge forms alive. Thus, we encourage the application of a gender focus in the formulation of development interventions related to agrobiodiversity maintenance.

Keywords: Agricultural biodiversity, agroecology, everyday life

Contact Address: Imke Scheepstra, Freie Universität Berlin, Inst. for Latin American Studies (LAI), Berlin, Germany, e-mail: imkes94@zedat.fu-berlin.de

Diversity and use of trees for food security in smallholder farming systems of Uganda

Fred Kalanzi[1], Isaac Kiyingi[1], Prossy Isubikalu[2], Florence Kyazze[2], Lawrence Orikiriza[2]

[1]*National Forestry Resources Research Institute, Uganda*
[2]*Makerere University, Dept. of Extension and Innovation Studies, Uganda*

Food production in Uganda has often been realised at the expense of forests and other biodiverse ecosystems. Yet, wild foods from forests and trees can be an essential micronutrient source, especially for poor smallholder farmers. With the ever-increasing population, integrating trees into farming systems offers a potential win-win solution to support dietary quality and the natural environment. Trees in agricultural systems improve soil health, regulate microclimates, enhance carbon sequestration and improve biodiversity at multiple scales. However, combining different tree species may also affect the level at which food security and nutrition are attained. This study assessed smallholder farmers' typology and tree species diversity for food security and nutrition. A cross-sectional survey of 277 randomly selected smallholder farmers who participated in the ACIAR-funded Trees for Food Security project was conducted. For each selected farmer, data on agroforestry technology used, number of trees and tree species diversity were collected at plot level using a tree inventory form. Focus group discussions were used to generate information on the linkage of tree diversity to food security and nutrition. Hierarchical cluster analysis was performed to determine smallholder farmer typologies and tree species diversity indices were computed and analysed for each typology. Two main groups of smallholder farmers could be distinguished: subsistence and pre-commercial. The tree species were distributed differently in the two identified groups. The tree species diversity was higher in subsistence farms than in pre-commercial farms. Across the predominantly used agroforestry technologies, tree species diversity was highest in intercropping, followed by boundary planting and woodlot. Subsistence farms showed a higher affinity to fruit tree species because they contribute directly to food security and nutrition. In contrast, pre-commercial farms were mostly dominated by trees of commercial value, such as Eucalyptus, mainly grown in woodlots. Therefore, we stress the critical role of smallholder farming systems in conserving on-farm diversity in the fragile eastern highlands of Uganda. The pre-commercial farms may sell tree products to buffer their income and enhance access to food. However, tree species diversity for enhancing farming systems' resilience in the face of climate change was high in subsistence farming households.

Keywords: Agroforestry technology, climate change, food security, nutrition, subsistence farms

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Contact Address: Fred Kalanzi, National Forestry Resources Research Institute, +256 Kampala, Uganda, e-mail: kalfrem@gmail.com

Characterisation of Indian mustard germplasm for agro-morphological traits and biotic stress tolerance

Rashmi Yadav[1], Ashish Kumar Gupta[2], Mahesh Rao[2], Jameel Akthar[1], Kartar Singh[1], Harinder Vishwakarma[1], Jai C. Rana[3], Raj K. Gautam[1]

[1]ICAR - National Bureau of Plant Genetic Resources, Division of Germplasm Evaluation, India
[2]ICAR - National Institute for Plant Biotechnology, India
[3]The Alliance of Bioversity International and CIAT, India

Oilseed Brassicas have become the third important edible oilseed crop next to soybean and palm in the world. The four main Brassica oilseed species, *B. napus*, *B. rapa*, *B. juncea* and *B. carinata* are widely cultivated for oil, condiment and vegetable purposes. *B. juncea* (L.) Czern, commonly referred as Indian mustard is a major oilseed crop in South Asia. We conducted an experiment to give a comprehensive account of the diversity characterisation using >2000 accessions of Indian mustard germplasm collected from 9 different agro-ecological zones of India and evaluated for 15 quantitative traits during the year 2020 to 2023. These accessions showed presence of highest variation for 1000 seed weight (coefficient of variation 48.57 %). PCA exhibited that plant height, silique length, length of main fruiting branch, 1000 seed weight, days to 50 % flowering and maturity were among the most important traits and accounted for more than 50 % phenotypic variation. Correlation studies indicated that plant height, leaf length, leaf width, days to 50 % flowering along with days to maturity should be considered while performing selection in segregating generations intended to improve seed yield/plant. Donors for various traits were identified e.g., IC426383, IC426386 for dwarf type (<70 cm); IC343199, IC589691, EC766320, IC426386 for early maturity (<95 days); IC491546, IC426322, IC355371 for seeds/siliqua (>22) and IC 383489 for oil content (45.2 %). New sources of resistance effective against multiple races of white rust (*Albugo candida*) e.g. EC766192, EC766164, IC265-495, IC443623, EC766061, EC766193, EC766595 and for sclerotinia rot (*Sclerotinia sclerotiorum* (Lib.) e.g. IC491577, EC766532, EC766516, EC766189 were identified with PDI=0 at different developmental stages of the plant. These novel sources of agronomic traits and host resistance will play vital roles to establish a strong genetic and molecular foundation for the mustard improvement program.

Keywords: *Albugo candida*, biotic stress, *Brassica juncea*, characterisation, *Sclerotinia sclerotiorum*

ID 954

Capability approach to wellbeing analysis: A case study of NTFP producing households in Iseyin, Nigeria

Kazeem Akanni Jimoh

Czech University of Life Sciences, Dept. of Economics and Development, Czech Republic

Wellbeing has been recognised to go beyond income and consumption issues but also encompasses health, nutrition, security, education, freedom, environmental integrity, social relations and affiliations. According to Amartya Sen theory, capability approach recognises wellbeing as the 'ability to be' or 'ability to attain some level of achievement' by the individual/household being considered.

This study was, therefore, carried out to examine the wellbeing status of non-timber forest product (NTFP) producing household in Iseyin LGA, Oyo State using capability approach. Primary data was collected through questionnaire administered to 120 respondents selected using multistage sampling technique. The NTFP households studied were involved in sheabutter processing, snailery, apiary and cane rat farming. The data were analysed using descriptive statistics, fuzzy set analysis and logistic regression. Fuzzy set theory was employed in measuring the well being indices using various dimensions while logistic regression was used in isolating the drivers of wellbeing in the households. The capability approach revealed that sheabutter producing households has the highest (0.101) capability wellbeing while apiary households' were the lowest (0.063). Age, household size and educational level have all been found to directly impact the wellbeing of the households such that, as they increase, so does their respective capability wellbeing increases. As regards the dimension used, assets has been revealed to have the highest (0.0955) capability wellbeing while access to natural resources was the lowest(0.0021). The isolated factors that drive capability wellbeing were identified as age group greater than 60 years, education as well as cooperative membership. Based on the findings, government should formulate policies that will encourage farmers to improve on their educational qualifications in order to attain higher wellbeing.

Keywords: Forest resources, livelihood, Nigeria, sustainable use

Contact Address: Kazeem Akanni Jimoh, Czech University of Life Sciences, Dept. of Economics and Development, Kamýcká 129, 165 00 Prague 6, Czech Republic, e-mail: jimoh@ftz.czu.cz

Agroecological services to improve the livelihoods of cocoa farmers in Côte d'Ivoire

Bonna Antoinette Tokou[1,2], Stefan Sieber[1], Constant Yves Adou Yao[2], Katharina Löhr[1]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

[2]*University Félix Houphouët-Boigny, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire*

Food security and households' well-being are pressing challenges facing cocoa farmers, especially in Côte d'Ivoire (West Africa). Cocoa production alone is rarely sufficient to generate a subsistence income for farmers or to support their families. The introduction of agroforestry follows the idea that, when the different cultural practices are taken into account, the economic profitability of the by-products of agroforestry systems and their usefulness leads to a more just and efficient design of sustainable production. Agroforestry is the voluntary integration of trees in agricultural landscapes, according to any spatial arrangement or temporal sequence, to obtain benefits from the ecological and economic interactions between these different components. Thus, producers' key is value addition and link to the market. This study aims to analyse the different cocoa growing systems of smallholder farmers in Côte d'Ivoire and the socio-economic utility of the associated trees. We consider the cocoa-based agroforestry system by analysing its importance from the point of view of improving income and contributing to ecosystem services for sustainable cocoa production, taking into account objective and climatic criteria: additional production (wood, fruit, fodder, etc.) or services (windbreaks, regulation of microclimate, shading, etc.). Thus, a diachronic approach allowed us to evaluate the system by estimating with the farmers using and monetary value they give each species according to its use at a time t. Floristic inventories of 625 m^2 in 80 cocoa plots followed by semi-structured interviews with plantation producers in five localities of Côte d'Ivoire were conducted. Quantitative analyses of the variables and statistical tests were carried out using SPSS software. Carbon storage of cocoa-based agroforestry systems was calculated. Thus, the systems are characterised according to their floristic characteristics and their contributions to socio-economic indicators. The results will contribute to designing and implementing agroforestry systems with better commercial potential and resilience to the agroecological context.

Keywords: Agroforestry, carbon storage, cocoa, livelihoods, smallholder

Contact Address: Bonna Antoinette Tokou, Leibniz-Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Müncheberg, Germany, e-mail: tokou.ant@gmail.com

Food system drivers of deforestation: An analysis of deforestation as an outcome of the food system

Janelle Sylvester[1,2], Diana M. Gutierrez[1], Lisset Pérez Marulanda[2,1], Martha Cristina Vanegas Cubillos[1], Augusto Castro-Nunez[1]

[1]*International Center for Tropical Agriculture, Climate Action, Colombia*
[2]*University of Copenhagen, Dept. of Geosciences and Natural Resource Management, Denmark*

According to the latest Global Forest Resources Assessment, approximately 90 % of global deforestation between 2000 and 2018 was attributable to agricultural expansion, positioning land use for food production as the greatest direct driver of deforestation. Studies investigating direct and underlying drivers of deforestation have generally employed a land systems approach, focusing on how interactions between human and environment systems influence land use and land cover change. Yet, despite the significant role of agricultural expansion in driving deforestation, limited research has explored deforestation through the lens of the food system. Consequentially, our understanding of the food system dynamics that drive deforestation for food production remains limited. In response to this research gap, this study proposes and operationalizes a novel framework for the study of food system drivers of deforestation. We use a critical analysis of frameworks and a systematic literature review of underlying drivers of deforestation to develop the framework and machine learning techniques (Extreme Gradient Boosting) to apply the framework at the global and continental scale to determine how drivers related to the three dimensions of the food system – (1) consumption/demand, (2) production/supply, and (3) trade/distribution – are influencing forest cover changes. The results indicate that demand- and trade-side dynamics are playing significant roles in driving deforestation at the global, Asia and Latin America scales, and that foreign direct investments (FDI), in particular, explained a large proportion of deforestation. This suggests that food system-based interventions could be effective in reducing deforestation in these regions and that greater attention should be given to the role of FDI in forest cover changes. Analyzing deforestation as an outcome of the food system can provide critical insights into where interventions within the food system are needed to reduce deforestation and how such interventions can be aligned with improving food security and nutrition as well as other sustainable development goals.

Keywords: Climate change mitigation, deforestation drivers

The urban jungle, an underexplored habitat for neglected and indigenous plant diversity

Emiel De Meyer[1], Pathy Kibungu[1], Jackie Epila[2]

[1]*Ghent University, Dept. of Plants and Crops, Belgium*
[2]*Lira University, Dept. of Science and Vocational Education, Uganda*

The Anthropocene, the current geological epoch in which human activity has become the dominant influence on the Earth's environment, is marked by globalisation and urbanisation. These processes have led to severe biodiversity decline and climate change. However, paradoxically, due to the same processes, urban environments have become melting pots of biocultural diversity. Cities provide for the needs of their inhabitants and beyond, acting as sinks for natural resources. These resources are mobilised through global trade and sourced from diverse rural communities globally, transported, traded, and marketed within urban environments. The use and cultivation of plant species from different regions and associated with diverse cultures and traditions contribute to the accumulation of plant diversity in urban areas. Consequently, urban contexts contain both cosmopolitan and globally distributed plant species, as well as region-specific, sometimes endemic, and rare plant species that frequently remain unnoticed. When biodiversity levels are high within this melting pot, urban contexts can become hotspots of present biodiversity. This opinion paper advocates exploring the urban context as an incubator of biocultural knowledge on plant diversity, as well as the possibilities of taking advantage of the opportunities presented by this introduced biodiversity. We propose several topics that require attention, including research, conservation, education, digitalisation, and policymaking. We believe that the urban context offers a unique set of resources that can contribute to developing sustainable solutions to the challenges we face due to the impacts of the Anthropocene, such as losses of agricultural and biological diversity, the vulnerability of food systems, and the erosion of biocultural knowledge.

Keywords: Biocultural diversity, forgotten crops, indigenous food systems, indigenous knowledge, urban ecology, urban ethnobotany

Contact Address: Emiel De Meyer, Ghent University, Dept. of Plants and Crops, Coupure Links 653, geb. A, 9000 Ghent, Belgium, e-mail: emiel.demeyer@ugent.be

Tree growing on farmlands in Rwanda: Farmers' preferences for adopting agroforestry in the eastern drylands

Jean Bosco Nkurikiye[1], Valens Uwizeyimana[1], Kato Van Ruymbeke[1], Iris Vanermen[1], Bruno Verbist[1], Alfred Bizoza R.[2], Liesbet Vranken[1]

[1]*KU Leuven, Earth and Environmental Sciences, Belgium*

[2]*University of Rwanda, Agriculture, Rural Development and Agricultural Economics, Rwanda*

In Rwanda, land degradation and effects of climate change and variability drive efforts towards land restoration with aim to make vulnerable smallholder farmers more resilient through investments in soil conservation and agroforestry. Effective agroforestry implementation requires involving farmers, and understanding their choices to adopt it. Still, there is little information about farmers' preferences for tree planting in Rwanda. Thus, this study explores these preferences in the country's eastern region. We conducted a discrete choice experiment to elicit preferences for tree attributes among 248 farmers. Eight attributes (number of woody and fruit trees, root system and canopy, change in maize yield caused by tree planting, frequency of extension visits, extra labour for tree management, distance from plot to tree nursery, and tree seedling cost) were selected after qualitative methods, and evaluated using mixed logit and generalised multinomial logit models to investigate preference and scale heterogeneity, respectively; and latent class model for class-specific preferences. Results show that farmers positively value planting woody and fruit trees on their farmlands. They prefer trees with deep roots and small canopy, and trees which would increase crop yields, but dislike increase in the tree seedling cost. WTP measures indicate that deep and shallow root systems with small canopy, seasonal visits, and change in maize yield are the most valuable attributes. However, there is preference and scale heterogeneity among farmers across agro-climatic zones. Farmers are split into two latent classes with notables similarities and differences in their preferences for agroforestry practices. Our findings demonstrate that farmers are willing to participate in agroforestry practices. They prefer woody trees for their products (timber, fire woods, stakes...), and fruit trees for their multi-functionality and role in food security and nutrition. This calls for increasing the share of fruit trees in agroforestry interventions. Furthermore, preferences for increased (maize) yields suggest focusing on N-fixing tree species; while preference for trees with deep root systems and small canopy calls not only for improved fruit varieties, but also for building farmers' capacity in tree management.

Keywords: Choice experiment, farmer preferences, land restoration, Rwanda

Contact Address: Jean Bosco Nkurikiye, KU Leuven, Earth and Environmental Sciences, 3000 Leuven, Belgium, e-mail: jeanbosco.nkurikiye@kuleuven.be

Socio-environmental drivers of local knowledge of climate change risk and woody species as fertilisers in Benin western Atacora (West Africa)

Thierry Dèhouégnon Houehanou

University of Parakou, Laboratory of Ecology, Botany and Plant Biology, Benin

Over the world, though climate change is threatening the human population, agroforestry through tree preservation is among the farming systems promoted to cope with such threats. Moreover, the risk of climate change may depend on socio environmental factors and consequently local people may not perceive in the same way the risk among different environment conditions. Though, one of the roles accomplishing by woody presence in cropping systems is their contribution to fertilisation, many local people may not perceive such knowledge. According to the protection motivation theory, we suggested that local people who perceive more the risk of climate change may more know and preserve woody as fertilisers in their cropping systems. The present study was conducted in western Atacora of Benin republic and aims to assess socio environmental drivers of local knowledge of (i) climate change risk and (ii) woody as fertiliser in traditional agroforestry parklands. The study zone experiences mostly natural resources degradation and therefore local people are more vulnerable to climate change, food insecurity and hunger. We used a random sampling technique to select 360 households' heads. Canonical and principal component analyses were used to characterise the environmental traits of the location of the selected farmers. Binomial logistic regression was used to assess the drivers of farmers' knowledge. The results showed that the local people in drier areas perceived the risk of climate change more than those in humid areas. Climate change risk perception, age, and membership in a farm organisation are the main drivers of the perception of woody as fertiliser as well as woody fertiliser preservation. The farmers belonging to a farm organisation and who preserve woody as fertilisers perceive the risk of climate change more than the opposite scheme, which results confirmed the protection motivation theory. The findings are helpful tools to sensitize the local people on climate change risk and the way to cope with the risk with woody species in agricultural lands.

Keywords: Agroforestry parklands, climate change risk, local ecological knowledge, woody fertilisers

Contact Address: Thierry Dèhouégnon Houehanou, University of Parakou, Laboratory of Ecology, Botany and Plant Biology, Parakou, Benin, e-mail: houehanout@gmail.com

Consumers' attitudes, purchasing intentions and preferences related to baobab fruit shell briquettes in Malawi

Peace-Efeh Ogbata, Dietrich Darr, Eleydiane Maria Gomes Vale

Rhein-Waal University of Applied Sciences, Fac. of Life Science, Germany

Malawian energy sector still suffers from insufficient energy supply coupled with the limited sources of energy. In addition, the constant use and high dependency on forest products especially firewood and charcoal for energy purposes causes the nation's forestry to be at a loss. Biomass briquette production is considered an alternative in the quest for energy product; however, briquette products are not widely used in Malawian communities despite its viability as a sustainable substitute for firewood and charcoal. Lack of awareness hinders the perceived benefits associated with briquette products and it will take conscious effort for its benefits to be widely recognised.

An innovative energy product, baobab fruit shell briquettes, has a great potential to fulfil the energy demand considering its abundance in the Malawian environs. The main aim of this study addressed consumers' attitude, purchasing intention and preferences towards the baobab fruit shell briquettes as an energy product. Utilizing structural equation modelling (SEM) analysis, factors such as subjective norms, purchasing behaviour, energy knowledge, perceived price and environmental concern had a significant positive influence on consumers' attitude and purchasing intention towards the potential energy product. Furthermore, this study implements a discrete choice experiments (DCEs) analysis of consumer's preference towards attributes of the potential energy product. Results showed that consumers showed a significant preference for an energy product that is available and accessible most time, and easy to use. These attributes were preferred more than other features of the product. Also, the study expanded the analysis to include moderating effect of variables such as location (urban and rural), education and income levels, on the relationship between consumers' attitude and purchasing intention. Only location had a significant moderating effect on the relationship between consumer's attitude and purchasing intention towards baobab fruit shell briquettes. In conclusion, the baobab energy product has a futuristic viable success upon establishment in the Malawian market despite other competitive energy product.

Keywords: Awareness index, baobab fruit shell briquettes, Malawi, purchasing intention

Contact Address: Eleydiane Maria Gomes Vale, Rhine-Waal University of Applied Sciences, Fac. of Life Sciences, Marie-Curie-Straße 1, 47533 Kleve, Germany, e-mail: eleydiane.gomes-vale@hochschule-rhein-waal.de

Socio-economic importance of *Borassus* palm parklands to the household of the Dallol Maouri of Gaya region, Niger

Djibrim Abdoulaye[1], Martin Wiehle[2], Larwanou Mahamane[1]

[1]*Abdou Moumouni University of Niamey, Rural Engineering, Waters and Forests, Niger*
[2]*University of Kassel, Tropenzentrum / Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany*

The Dallol Maouri *Borassus* parkland – an agroforestry system consisting mainly of *Borassus aethiopum* Mart. (Arecaceae) – is the largest in Niger, located in its south-eastern department of Gaya. It covers an area of approximately 30,000 ha and is dominated by intercropped millet, rice, sorghum and cowpea fields. Over the millennia, forest has been converted into this parkland which serves multiple uses for humans, livestock and wild game. In the last couple of decades, the use has partly exceeded its natural carrying capacity, thus it is important to study the status and potential threat of these palm stands. For this study, we used the software QGIS, to adopt a sampling plan with probability proportional to size, which enabled us to select 13 villages with a maximum distance of 7 km to the next stand. By means of a sample number determination equation (n= N/(1+N(e2)), we selected 234 agricultural households, i.e. 18 agricultural households per village. Exploitation and income from the palm products were assessed by interviews. Results suggest that all parts of this palm tree are used, despite some of the parts' use is prohibited by law. Most of the benefits came from the marketing of non-wood products, such as green and ripe fruits (13 %) as well as the hypocotyl, which is the seedling after 3–4 months of seed germination (87 %). The hypocotyl is transported and sold both at the level of local and regional markets, as well as main cities but also at the level of the neighbouring country Nigeria. The hypocotyl and fruits provided farmers with an average net annual income of 76,400 FCFA (maximum of 960,000 FCFA). In 6 % of the cases, the analysis showed that the contribution of *B. aethiopum* to family agricultural income is 10 %. However, it appears that some human practices (trunk cuttings, use of male flower, green petiole harvest) and wind abrasion, threatens the sustainable exploitation of these *B. aethiopum* stand in certain localities. Thus, adopted management strategies should be in place to enable the long-term survival of these stands and thus a continues income strategy for rural people.

Keywords: African fan palm, income generation

Contact Address: Djibrim Abdoulaye, Abdou Moumouni University of Niamey, Rural Engineering, Waters and Forests, Lamorde Municipality, BP 10960 Niamey, Niger, e-mail: djibrim22@yahoo.fr

ID 186

Management and biodiversity in agroforestry and tree systems

Online posters

Multispectral drone image analysis for shade tree species characterisation in cocoa agroforestry systems

Nikolas Piont Konwski Grünther[1], Munir Hoffmann[2], Gennady Bracho Mujica[1], Reimund P. Rötter[1], Issaka Abdulai[1]

[1]University of Goettingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany, Germany

[2]AGVOLUTION GmbH, Germany

Previous studies on cocoa agroforestry systems have shown the potential to diversify the production, increase cocoa yield and thereby increase farmers income. On the other hand, negative impacts of shade trees on cocoa production can lead to lower yields compared to monocultures. Conventional studies in understanding the impact of shade trees in cocoa agroforestry have mainly focused on manual observation and direct measurements which are usually time and resource demanding and hence limiting the spatial extend as well as the number of species that are studied. Analysis of drone acquired high resolution multispectral images for evaluation biotic and abiotic stress in agricultural research is gaining high popularity but their application in agroforestry systems, especially in the tropics is limited.

This study focuses on comparing shade tree species specific spectral indices (e.g. NDVI, NDRE, ...) over different seasons in a multi species cocoa agroforestry systems in Ghana. Nineteen (19) shade trees species belonging to different functional groups based on leaf phenology were selected. Tree morphological traits (DBH, height, canopy area) and leaf phenology were recorded for 8 randomly selected individual shade trees of each species. From a subset of 13 shade trees species belonging to the various functional groups, the relationship between spectral indices and leaf nutrient content will be analysed. Therefore, the central research question is whether significant differences in spectral traits exist among specific shade tree species and respective functional groups and their variability over different seasons.

Multispectral drone images were collected with DJI Multispectral drone during late wet season of November 2021, peak dry season of February 2022 and mid wet season of July 2022 across 10 smallholder cocoa plantations of similar age in Ghana. Further analysis of shade tree traits and interactions with cocoa trees through drone image analysis could contribute to a deeper understanding of cocoa agroforestry systems functioning through innovative research approach.

Keywords: Cocoa agroforestry, functional traits, remote sensing, shade tree species, spectral indices

Contact Address: Nikolas Piont Konwski Grünther, University of Goettingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany, Maschmühlenweg 5, 37077 Goettingen, Germany, e-mail: Nikolas.PKG@outlook.com

Decomposition and nitrogen release patterns of shrubs/trees leafy biomass in the Sahelian zone of Senegal in West Africa

Siriki Fane[1], Deogratias Kofi Agbotui[1], Cheikh Ndiaye[2], Mariko Ingold[1], Sophie Graefe[1], Andreas Buerkert[1]

[1]University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

[2]China Agricultural University (CAU), College of Resources and Environmental Sci., China

In open-parkland systems of the West African Sahel, farmers often apply leafy plant biomass to their croplands to maintain soil productivity. Nonetheless, there is a need for research that examines how shrub and tree leaf biomass decompose and mineralize to better understand processes of nutrient cycling in these agroecosystems. The present study therefore aims at monitoring decomposition and nitrogen (N) release of leafy biomass of selected shrub and tree species from the region. Using the litterbag technique, our study was conducted in the Louga Region of Senegal with leaves of *Faidherbia albida* (Delile) A.Chev., *Pterocarpus lucens* Lepr., *Guiera senegalensis* J. F. Gmel., and *Piliostigma reticulatum* (DC.) Hochst. Each litterbag was filled with 26 g of leaves which were placed on the soil surface and sampled at weeks 2, 4, 8, and 16. Decomposing leaves lost on average 30 % of their initial dry weight in the first four weeks after placement. At weeks 2, 4, 8, and 16, DM losses of *F. albida* were with 43 %, 43 %, 51 %, and 44 %, respectively, significantly ($p < 0.05$) larger than those of *G. senegalensis*. Only at week 2 average N releases of *F. albida* and *P. lucens* were significantly (9 %, $p < 0.05$) higher than of *G. senegalensis* and *P. reticulatum*. Nitrogen fixing trees and shrubs species (*F. albida* and *P. lucens*) had a higher decomposition and nitrogen release because of their lower C/N ratios. To improve application efficiency for crop yields, use of mulched leaves should be tailored depending on the type of leafy biomass to optimize synchronization of nutrient release with crop nutrient demands.

Keywords: Agroforestry, litter quality, litterbag technique, nutrient cycling, organic agriculture

Contact Address: Siriki Fane, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstr. 19, D-37213 Witzenhausen, Germany, e-mail: siriki.fane@mesrs.ml

Tree diversity and aboveground carbon stocks in push-pull systems in western Kenya

Elisheba Imbaya, Moses Gichua, Samuel Were, Shem Kuyah
Jomo Kenyatta University of Agriculture and Technology, Botany, Kenya

Push-pull technology is a companion cropping system that is effective in soil fertility improvement and management of stemborers, fall armyworms, and *Striga* weed in cereals. Trees in agricultural landscapes are considered a remedy for climate change mitigation by storing carbon in soils and woody biomass. However, this potential has not been quantified in push-pull systems. Therefore this study aimed to determine the diversity and carbon stocks of trees under push-pull systems in Siaya, Vihiga, and Kisumu counties in western Kenya. A total of 45 farms representing five land use categories namely: Homestead, trees within cropland, woodlots, boundary planting, and trees in grazing land were randomly selected from a list of push-pull farmers obtained from the International Centre of Insect Physiology and Ecology. An inventory of trees was conducted capturing the species name, diameter at breast height (DBH), farm size, and area of various land use categories. DBH was used to estimate aboveground biomass and carbon stocks. A total of 9159 trees, belonging to 97 species were inventoried over 33.968 ha. The highest abundance and species richness were recorded in Vihiga while the highest diversity index was recorded in Siaya. The highest abundance was recorded by woodlots while the highest species richness and Shannon diversity index was recorded by homestead in all the sites. The highest aboveground carbon estimates per farm were recorded in Kisumu at $12.10\,\mathrm{Mg\,ha^{-1}}$ while the highest carbon stocks were recorded by woodlots in all the sites. The tree species that contributed to higher aboveground biomass in all sites were *Eucalyptus* species (22.7 %) and *Grevillea robusta* (22.8 %). Small trees with DBH < 10 cm were the most dominant (77.6 %) in all the study sites but held the least biomass (4.8 %). Large trees with DBH > 40 cm were fewer (1.1 %) but held more biomass (33.1 %). This study's aboveground biomass and carbon stocks provide useful information in mitigating climate change. Smallholder push-pull farmers should also be encouraged to promote the conservation of tree diversity, particularly in woodlots and homesteads that recorded higher carbon stocks.

Keywords: Aboveground biomass, carbon stocks, climate change, diameter at breast height, push-pull systems, Shannon diversity index

ID 751

Land-use effects on plant and arthropod diversity in South African savannahs

Kai Behn[1], Bianca Greyvenstein[2], Frances Siebert[2], Johnnie van den Berg[2], Vincent Mokoka[3], Catrin Westphal[4], Sara Yazdan-Bakhsh[5], Jan-Henning Feil[6], Stefan Foord[7], Ingo Grass[8], Reimund P. Rötter[4], Peter Taylor[9], Anja Linstädter[10]

[1]University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany

[2]NorthWest University, School of Biological Sciences, South Africa

[3]University of Pretoria, Dept. of Geography, Geoinformatics and Meteo., South Africa

[4]University of Göttingen, Dept. of Crop Sciences, Germany

[5]University of Göttingen, Dept. of Agricultural Economics and Rural Development, Germany

[6]South Westphalia University of Applied Sciences, Agricultural Economics and Digital Farm Management, Germany

[7]University of Venda, SARChi Chair on Biodiversity Value and Change, South Africa

[8]University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

[9]University of the Free State, Zoology and Entomology Department and Afromontane Research Unit, South Africa

[10]University of Potsdam, Inst. of Biochemistry and Biology, Biodiversity Research / Syst. Botany, Germany

Savannah ecosystems in southern Africa are biodiversity hotspots and are highly important for various ecosystem services. They are increasingly threatened by land-use intensification, with mostly negative consequences on biodiversity. Along the intensification pathway, near-natural savannahs are typically first converted into rangelands, then into croplands, and finally into intensively used homegardens. However, land-use intensity in croplands and homegardens also depends on the farmer´s socio-economic background. Thus, our study addresses the following questions: (1) How does land-use intensification affect the taxonomic and functional composition, and diversity of plant and arthropod communities? (2) Do farmers' socio-economic background play a role in this context?

We conducted our study in South Africa's Limpopo province. Climate is semi-arid, and natural vegetation is a thornbush savannah. We sampled in four land-use types along the intensification pathway, i.e. a game reserve with near-natural vegetation, communal rangeland, cropland, and homegardens. Plot selection in cropland and homegardens was stratified into four

socio-economic classes based on household surveys. Field assessments of vascular plants and arthropods (via pan and pitfall traps) were conducted in the vegetation period 2020/21. To assess and compare diversity, we performed PERMANOVA, and calculated Shannon- and association indices.

We found that plant and arthropod communities differed strongly across land-use types. Many species were only recorded in one type, and the dominances of functional groups varied. The game reserve was dominated by native, perennial grasses with high forage value. In the rangelands, they were replaced by annual grasses. Annual forbs, many of them introduced species, were common in the croplands and home gardens. For arthropods, similar patterns were observable, with agricultural pest species restricted to croplands. Farmers' socio-economic background influenced diversity in home-gardens, with richer households had lower arthropod diversity.

Land-use intensification in the savannah biome increased overall diversity of plants and arthropods. However, many native wild species were lost outside of the protected area, among them valuable forage grasses. Protected areas are therefore of critical importance for biodiversity conservation, as they can act as refuge for useful wild plants and beneficial arthropods. Education of farmers on beneficial arthropods may further help to reduce losses in these species groups.

Keywords: Beneficial arthropods, biodiversity, ecosystem functions, game reserve, home gardens, Limpopo, rangeland, smallholder farmers, vegetation

Exploring regenerative agriculture using photovoice: The case of the Mau Narok-Cheregany Complex in Kenya

Ndungu S. Nyokabi, Henrietta L. Moore

University College London, Institute for Global Prosperity, Kenya

Maize monocrop systems have led to land degradation, soil erosion, and loss of biodiversity in Kenya. A transition to agroecological farming and establishment of agroforestry and silvopastoral systems could increase tree cover and reduce farmers' exposure to climate change, while creating new livelihood opportunities and increasing rural prosperity.

Several studies have explored regenerative agriculture in Kenya, however, this research has not been farmer-led or participatory. This study responds to this research gap by adopting a farmer-led, participatory, visual research approach to exploring the future of regenerative agriculture in Kenya.

In this study, we used photovoice - a participatory, visual method - to explore farmers' adoption of regenerative agricultural practices in the Mau-Narok- Cherangany Complex. Farmers were purposively selected based on their willingness to participate in the study; possession of a smart-phone with a camera; and a minimum of three years of farming experience. Farmers took photographs of the regenerative agricultural practices they had adopted in their farms and shared these photographs with the lead researcher via WhatsApp messenger. The photographs were printed and a discussion was held with farmers to further elaborate on and explore the stories they wanted to communicate with their images.

The photographs revealed that farmers had adopted a range of regenerative agricultural practices, from agroforestry involving the planting of coffee, bamboo, mango, avocado, and timber and medicinal trees in response to growing demand from the local and global markets for fruits and timber and non-timber products. The incorporation of trees into farming systems and a move away from maize grown as a monocrop created new economic livelihood opportunities for farm households, such as bee keeping, and generated wood for construction and fire wood. Farmers reported that the introduction of bamboo and terraces had resulted in the recovery of a local stream that had dried out; reduction of soil erosion and improvement of the riparian areas; and had increased insect and bird biodiversity by providing habitat.

The findings of this study underscore the importance of policymakers and practitioners supporting farmers in transitioning from monocrop system to more resilient perennial tree-crop-based, multi-species farming systems.

Keywords: Agroforestry, regenerative agriculture, silvopastoral, trees, visual research methods

Contact Address: Ndungu S. Nyokabi, University College London, Institute for Global Prosperity, Kiserian, Kenya, e-mail: ndungukabi@gmail.com

Biodiverse resilient forest landscapes as engines for sustainable agriculture and food security

Claudia Raedig[1], Stefan Porembski[2], Udo Nehren[1], Sabine Schlüter[1]

[1]*TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Germany*
[2]*University of Rostock, Inst. of Biosciences, Dept. of Botany and Botanical Garden, Germany*

Expanding agri-food production puts pressure on forests globally and pushes their fragmentation and degradation, at times up to the point of deforestation. Biodiverse forests are essential prerequisites for the provision of ecosystem functions and services, which are vital for food production and thus food security in the surrounding areas. Considering the drastic effects of climate change, especially the increased frequency and intensity of extreme weather events such as droughts, floods and storms, the ecosystem functions of biodiverse forest are becoming increasingly vital for food production systems.

The present study aims at comparing three forest landscapes in three countries, Mozambique, Madagascar and Brazil, to explore the possibility to enhance local food security and sustain productivity of agriculture systems close to forests. These three forest landscapes each consist of forest areas put under pressure by surrounding agricultural areas. Factors affecting the level of encroachment on the remaining forest areas are compared such as the level of primarily need driven invasion from local settlements for extractive uses. As potentially favorable factors, the comparative analysis will look into identified forest ecosystem functions and services, the respective protection status of the forests as well as possible strategies for more sustainable agriculture and food security in the surrounding areas. To specify these potentials more precisely, selected strategies will be reviewed, like forest conservation measures, nature based solutions for disaster mitigation and evolving marketing options for sustainable value chains of neglected and underutilised species (NUS) in the forest-agricultural landscape will be explored, and for each forest landscape, an integrating portfolio for agroecological transition pathways can be proposed.

Keywords: Agroecological transition pathways biodiverse resilient forest landscapes, food security, sustainable agriculture

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Contact Address: Claudia Raedig, TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Betzdorfer Straße 2, 50679 Köln (Deutz), Germany, e-mail: claudia.raedig@th-koeln.de

Vanilla wild relatives naturally occurring in Atlantic rainforest–central biodiversity corridor in southern Bahia – Brazil

Marina Rosa de Souza, Taina Soraia Muller

Federal University of the South of Bahia, Master's Degree Programme in Science and Sustainability, Brazil

The genus *Vanilla* Mill., due to being a source of vanillin, an aromatic organic compound with high commercial value, is one of the best-known of the Orchidaceae family. The extracted oil has been used in the food, pharmaceutical, and cosmetics industries. Considering the complex activity of growing vanilla for oil extraction, studying species of this genus is of huge interest for conservation and breeding programs. The current study was carried out in the extreme south of the state of Bahia, in northeastern Brazil. A region characterized by the presence of many traditional communities and small farmers, and human development index below the OECD average. The study area covered four different provenances, including the conservation unit "Descobrimento National Park" and its surrounding communities, and aimed to identify the naturally occurring *Vanilla* species. Expeditions were carried out in the forest with the purpose to find and register specimens using geo-location for further monitoring and data collection on the morphology, habitat, floral visitors, and floral phenology. The observation of the reproductive organs occurred weekly/daily for a period of 60 days, from the flower bud stage until the first flower has fallen naturally. Fifteen specimens were marked all over the studied area, three of them were blossoming and provided data for this study. Through the analysis of the morphological and phenological characteristics of the observed flowers, it was possible to identify with certainty two species, *Vanilla phaeantha* Rchb.f. and *Vanilla chamissonis* Klotzsch. These results contribute to determining and registering vanilla wild relatives' occurrence in the extreme south of Bahia. In addition, relevant information was generated on phenological, and morphological aspects of the species found in this environment.

Keywords: Floral biology, Orchidaceae, vanilla, wild relatives

Contact Address: Taina Soraia Muller, Federal University of the South of Bahia, Master's Degree Programme in Science and Sustainability, Rua América Latina n° 491 Recanto do Lago, 45987132 Teixeira de Freitas, Brazil, e-mail: tainamuller@ufsb.edu.br

Influence of coffee agroforestry systems on soil carbon stock and carbon mineralisation: A case study in northern Thailand

SASIPRAPA KULLACHONPHURI[1], PHONLAWAT SOILUEANG[2], NIPON MAWAN[1],
YUPA CHROMKAEW[2], SUREERAT BUACHUN[3], WIRIYA SANJUNTHONG[1],
SUWIMON WICHARUCK[4], NUTTAPON KHONGDEE[1]

[1]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*
[2]*Chiang Mai University, Dept. of Plant and Soil Science, Thailand*
[3]*Rajamangala University of Technology Lanna Phitsanulok Campus, Thailand*
[4]*Chiang Mai University, Energy Technology for Environment Research Center, Thailand*

Deforestation affects soil carbon stock due to the soil environment under the canopy and the root systems of each plant species determine soil carbon mineralisation process. In the upper north of Thailand, forest area has recently been converted to agricultural area in particular coffee plantation. Therefore, the objective of this research was to assess soil carbon stock and carbon mineralisation in various coffee agroforestry systems. The study site was located at the Arabica coffee plantation of the Nhong Hoi Highland Agricultural Research Station in Chiang Mai province, Thailand. This study included four land use types: (1) forest (comparing site), (2) coffee monoculture, (3) coffee grown with forest, and (4) coffee grown with fruit trees. To investigate soil carbon stock, nondestructive soil samples were taken at three different soil depths: 0–20 cm, 20–40 cm, and 40–60 cm. For carbon mineralisation study, destructive soil samples at topsoil layer (0 – 20 cm) were taken into the laboratory for the incubation experiment. The soils were then sampled at day 1, 4, 7, 14, 21, 35 and 65 after incubation for dissolved organic carbon (DOC) and CO_2 emission analysis. This study revealed that the coffee with fruit trees at topsoil layer (0–20 cm) had the lowest soil carbon stock, followed by coffee monoculture and the forest, while the soil from the coffee grown with the forest had the highest soil carbon stock. The soil carbon stock at 20–40 and 40–60 cm depths did not differ ($p > 0.05$) between each land uses. Regarding DOC, forest soil was found to be considerably higher than coffee monocrop and coffee grown with fruit trees ($p < 0.05$), with DOC values of 25.23 mg kg^{-1}. Coffee monoculture had the lowest DOC (22.56 mg kg^{-1}). Cumulative CO_2 emission showed that coffee grown with forest contributed the highest CO_2 emission (10.3 mg kg^{-1}) while forest had the lowest value of CO_2 emission (4 mg kg^{-1}). Combined coffee and forest cultivation can boost biodiversity more than coffee monoculture. Coffee cultivation in association with forests or perennial fruit trees can be options for sustainable Arabica coffee cultivation in Northern Thailand.

Keywords: Agroforestry systems, Arabica coffee, land use change, soil microbial respiration

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Contact Address: Nuttapon Khongdee, Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Huay Kaew Road, 50200 Chiang Mai, Thailand, e-mail: nuttapon.k@cmu.ac.th

Seasonal dynamics of soil carbon and nitrogen stocks with various coffee agroforestry systems in Thailand

Phonlawat Soilueang[1], Nipon Mawan[2], Yupa Chromkaew[1], Sureerat Buachun[3], Wiriya Sanjunthong[2], Narit Yimyam[2], Suwimon Wicharuck[4], Nuttapon Khongdee[2]

[1]*Chiang Mai University, Dept. of Plant and Soil Science, Thailand*
[2]*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand*
[3]*Rajamangala University of Technology Lanna Phitsanulok Campus, Thailand*
[4]*Chiang Mai University, Energy Technology for Environment Research Center, Thailand*

Agroforestry is an alternative agricultural system that can help reduce deforestation, soil erosion, and other environmental issues caused by deforestation. This combination of forest and agriculture can serve as a carbon and nitrogen sink and source. However, seasonal change alters the capacity to store carbon (C) and nitrogen (N) in soil. Therefore, the purpose of this study was to evaluate seasonal dynamics of soil carbon and nitrogen stocks in different coffee agroforestry systems. The study site was conducted at the Nhong Hoi Highland Agricultural Research Station in Chiang Mai province, Thailand. This study included four land use types: (L1) forest, (L2) coffee monoculture, (L3) coffee grown with forest, and (L4) coffee grown with fruit trees (Persimmon). The data was collected in two seasons including rainy and cold seasons. For soil carbon and nitrogen stocks, soil samples were taken at three soil depths: 0–20, 20–40, and 40–60 cm. Soil physico-chemical, and biological properties were analyzed. Moreover, litter traps were used to capture fallen biomass from associated plant species. The results indicated that seasonal changes had no effect on the dynamics of soil carbon and nitrogen stocks $(0-60\,cm)$ $(p > 0.05)$. During the rainy season, L3 had the highest soil carbon stock $(71.21\,t\,C\,ha^{-1})$ at 0–20 cm, while L4 had the lowest $(37.41\,t\,C\,ha^{-1})$ $(p < 0.05)$. L3 had the trend of having highest soil carbon stock, but there was no statistically significant difference among land use types at $20-40\,cm$ and $40-60\,cm$. While seasonal dynamics had the effect on soil nitrogen stock $(0-60\,cm)$ $(p = 0.021)$, rainy season contributed to higher soil nitrogen stock as compared to cold season. N fertiliser application in coffee agroforestry systems led to higher soil nitrogen stock during rainy season $(9.64\,t\,N\,ha^{-1})$, while cold season had $7.82\,t\,N\,ha^{-1}$. During rainy season, L3 had the highest soil nitrogen stock at $0-20$ and $20-40\,cm$, which the values were 6.09 and $3.58\,t\,N\,ha^{-1}$, respectively. However, L1 had the highest soil nitrogen stock in all soil depths during cold season.

Keywords: Agroforestry systems, Arabica coffee, highland, northern Thailand

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Contact Address: Nuttapon Khongdee, Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Huay Kaew Road, 50200 Chiang Mai, Thailand, e-mail: nuttapon.k@cmu.ac.th

Aboveground biomass models for trees and shrubs of exclosures in the drylands of Tigray, northern Ethiopia

Mengesteab Hailu Ubuy[1], Tron Eid[2], Ole Martin Bollandsas[2], Emiru Birhane Hizikias[1]

[1]*Mekelle University, College of Agriculture and Natural Resource Management (CoANR), Land Resource Management and Environmental Protection (LaRMEP), Ethiopia*
[2]*Norwegian University of Life Sciences (NMBU), Fac. of Environmental Sciences and Natural Resource Management, Norway*

Globally, drylands cover large areas, but few models for estimation of biomass are developed for the relatively complicated tree and shrub structures found in this particular environment. The main objective was to develop aboveground biomass models generally applicable for all exclosures in the region. A first set of general aboveground biomass models for exclosures in the drylands of the Tigray region, northern Ethiopia were developed from a large dataset with 305 destructively sampled trees and shrubs covering 50 different species and distinct growing conditions. Since biomass revealed nonlinear relationships to the independent tree variables, we used a nonlinear least square modelling technique when fitting models. Selection of models was based on Pseudo- R^2, and root mean square errors and mean prediction errors (MPEs) from a leave-one-out-cross-validation procedure. Pseudo- R^2 and relative (MPEs) of the models varied from 0.76 to 0.84 and -3.7% to -1.5%, respectively. The large prediction errors observed when testing the "pan-tropical" models on our data, not only demonstrated the importance of developing the new models, but also indicated that careful considerations should done if the "pantropical" are planned for application in drylands elsewhere than Ethiopia. The new models may be applied generally for exclosures in Tigray region for decision-support in forest management and as basis for reporting changes in carbon stock as required in the reducing emissions from deforestation and forest degradation (REDD+) mechanism. Since no other appropriate model options exist, we recommend our set of general aboveground biomass models to be applied generally for large-area estimates of aboveground biomass of timber and fuelwood of exclosures in the region.

Keywords: Aboveground biomass, crown width, destructive sampling, exclosures, wood basic density

Contact Address: Mengesteab Hailu Ubuy, Mekelle University, College of Agriculture and Natural Resource Management (CoANR), Land Resource Management and Environmental Protection (LaRMEP), P.O Box 231 Arid Campus, Mekelle, Ethiopia, e-mail: mengesteabh@gmail.com

Analysis of the diversity and timber potential in cocoa agroforestry systems in alta Verapaz, Guatemala

Carlos Enrique Villanueva Gonzalez[1], Alejandro Ruiz-Chután[1], Marie Kalousová[1], Cristobal Villanueva[2], Bohdan Lojka[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Czech Republic*
[2]*CATIE, Costa Rica*

The production of timber in agroforestry systems holds immense potential in promoting environmental and economic sustainability, particularly for rural families. Despite its significance in Guatemala, little is known about the potential of timber and its contribution to the sustainability of traditional agroforestry systems. This study aims to analyse the timber resource in cocoa agroforestry systems of different ages and evaluate variables such as floristic composition, species diversity, and potential for timber production from the species present in the evaluated systems. To achieve this objective, the researchers established 20 temporary sampling plots and measured dasometric variables in each plot, including total height (th), commercial height (ch), and diameter at breast height (DBH) of the inventoried species. The presence of species was statistically analysed using cross-tabulation and Pearson's Chi-square test ($\chi 2$) to determine the frequency distribution of species among the ages of the evaluated agroforestry systems. The study identified 827 trees of 38 species belonging to 19 families. The most represented species within the age range of the evaluated systems were *Gliricidia sepium* (Jacq.) Kunth. (35.07 %), *Swietenia macrophylla* G.King (19.11 %), and *Inga sapindoides* Willd (7.62 %). The trees occupied a basal area of 33.29 m^2, and a total volume of 352.35 m^3 was recorded, of which 148.9 m^3 were for commercial use. The most frequent uses were firewood (38.21 %), thin plank (30.23 %), and poles (22.85 %), while the use of thick planks was the least common (8.71 %). The study highlights the wide diversity of shade tree species present in cocoa agroforestry systems, indicating their significant potential for timber production, especially for firewood. This information is relevant for the planning of management and conservation strategies for cocoa agroforestry systems in the region.

Keywords: Botanical composition, cocoa agroforest systems, dasomestric variables, species diversity, timber production

Contact Address: Marie Kalousová, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, 16900 Prague, Czech Republic, e-mail: marie.kalousova@gmail.com

The impact of agroforestry systems on the reduction of forest fires. A case study in the tropical Andes of Cochabamba, Bolivia

MIGUEL ANGEL CENTELLAS LEVY

Abril Foundation, Bolivia

Forest fires represent one of the major threats to biodiversity conservation; a considerable number of these events are strongly related to agricultural expansion, especially in developing countries. In many rural communities from the Bolivian tropical Andes, forest and grassland fires have been a recurring problem for the last decades. Many of these fires are caused by local farmers, attempting to open land for agriculture and cattle farming by a widespread practice called "supervised fires", but often, due to environmental conditions like high wind speed, steep slopes, and dryness (this practice is common during the dry season), they lose control of it. Local fire reports and interviews with rural farmers state that both frequency and intensity of fires have been reduced in recent years in areas where agroforestry systems have been introduced as a new way of agricultural production. Remote sensing tools, such as the normalized burn ratio index, the MODIS/Terra+Aqua burned area monthly L3 global 500 m SIN grid, and the Hansen global forest cover change v 1.9 database were used to corroborate such information. The results show a reduction pattern in the extension of burnt areas since the implementation of these systems, showing their positive impact in terms of environmental conservation, with special attention on *Polylepis* spp. forests, a threatened native genus that is currently displaying a good conservation status in the study area. Besides the environmental aspect, these agroforestry systems represent an attractive economic alternative for rural farmers, as they diversify their production, and reduce the dependency on agrochemical products. Moreover, this paradigm change implies one step further towards sustainable development and climate resilience.

Keywords: Agroforestry systems, conservation, forest fires, remote sensing

Contact Address: Miguel Angel Centellas Levy, Abril Foundation, 017 papa clemente street, 3564 Cochabamba, Bolivia, e-mail: macnpp@hotmail.com

ID 359

Crop-livestock integration in urban agriculture: Implication for urban food security in Ghana

Iftikhar Alam[1], Martin Wiehle[1], Muhammad Arslan Nawaz[1], Annette Braun-Lüllemann[2], Oliver Gailing[3], Markus Müller[4], Andreas Buerkert[1]

[1]*University of Kassel, Organic Plant Prod. and Agroecosyst. Res. in the Tropics and Subtropics, Germany*

[2]*Pomologenverein, Germany*

[3]*Georg-August University of Göttingen, Center for Integrated Breeding Res., Germany*

[4]*Georg-August University of Göttingen, Dept. of Forest Genetics and Forest Tree Breeding, Germany*

Apricot fruits constitute an economically and ecologically important horticultural crop in Gilgit-Baltistan, N-Pakistan. Its high nutritional, medical, and economic value is appreciated by farmers and consumers of the region. An astonishing rich diversity of local landraces is available in the area of which many appear to be rare, are undocumented, and may be thus at risk of extinction, since modern varieties and cash-crop fruits like cherry are alternatively cultivated. To assess the current use, management, and diversity of apricot, 52 households of 15 villages in five valleys and two research centres were visited and a total of 240 landraces collected and morphologically as well as phenotypically characterised. Alpha and beta diversity was calculated to assess landrace richness and diversity measures within and across villages, valleys and the two regions Gilgit and Baltistan. The information derived from 12 microsatellite markers was used to assess genetic variation and structure. The results of two cluster analyses of morphological and genetic parameters were merged into a tanglegram by means of cophenic correlation matrices. A total of 122 vernacular names of apricot landraces were recorded; the most dominant are Halman, Habi, Karfo chuli, and Shikanda. Among five valleys, the mean Simpson index was 0.94 while mean genetic diversity (He) was moderate (0.729). The overall weighted β diversity was 0.737 of which the Gilgit region captured the largest diversity. Negative inbreeding coefficients indicated a moderate excess of heterozygotes in all groups. A moderate correlation (r = 0.45, p = 0.001) between phenotypic and genetic dendrograms suggested genetically linked apricot stone traits. We were also able to identify true-to-type, synonym, and homonym samples. Considering the high phenotypic and genetic variability, Gilgit-Baltistan appears a promising source of apricot germplasm for future breeding programs. The promotion of local varieties may allow farmers to diversify their production and derived sources of income as well as to maintain a historically important bio-cultural heritage of Gilgit-Baltistan. Comprehensive conservation strategies, combined with further participatory research, will be needed to achieve this goal.

Keywords: Dead end valleys, livelihood, microsatellite markers, tree management, varietal richness, α and β diversity

Assessment of accession integrity over continued regeneration of genebank germplasm

Alemayehu Teresssa Negawo[1], Meki Shehabu Muktar[1], Chris S. Jones[2], Alice Muchugi[2]

[1]*International Livestock Research Institute (ILRI), Ethiopia*
[2]*International Livestock Research Institute (ILRI), Kenya*

ILRI holds over 18,000 accessions of tropical and subtropical grass and legume forages in its 'in trust' collection. Annually hundreds of samples are requested and distributed to researchers and forage seed producers. To ensure the continuous availability of seeds, accessions are regenerated in the field to replenish exhausted inventory. Thus, a rationalized strategy is required to ensure the integrity of the germplasm over continuous generations to maintain stocks of seeds for distribution. In such effort, it is important to know the implication of continuous regeneration on the genetic integrity of accessions. Therefore, the aim of this project was to assess the effect of continued regeneration on integrity of germplasm in the genebank. Thus, we used genotyping data to assess the genetic integrity of accessions over continued regeneration in three forage species namely *Lablab purpureus*, *Vigna unguiculata* and *Stylosanthes capitata*. Accessions with the largest number of lots from the three forage species were selected and used for this study. Genomic DNA was extracted from young leaves collected from actively growing seedlings in the greenhouse and genotyped on the DArTSeq platform. The generated markers were subjected to different analyses such hierarchical clustering, principal component analysis (PCA), genetic relationship matrix (GRM), probability of identity by descent and genetic distance. The result showed that in most cases the lots from the same accession clustered together with genetic similarity close to 1. In a few cases, the lots from accessions clustered in two groups. In general, the result shows the importance of good management practices and the need to have quality insurance/control protocol during seed production and processing to ensure integrity of germplasm conserved in genebank.

Keywords: Genebank, genetic integrity, genetic similarity, germplasm

Contact Address: Alice Muchugi, International Livestock Research Institute (ILRI), Nairobi, Kenya, e-mail: a.muchugi@cgiar.org

ID 726

Revealing the genetic diversity of *Pinus merkusii* in Aceh via simple sequence repeat (SSR)

Rita Andini[1], Enny Rimita Sembiring[1], Muhammad Ikhsan Sulaiman[2], Arsyad Alhadi[2], Joko Ridho Witono[3], Izu Andry Fijridiyanto[3], Sapto Indrioko[4], Heru Prono Widayat[2], Erika Pardede[5]

[1]*National Agency of Research and Innovation (BRIN), Genetic Engineering Research Group, Indonesia*

[2]*Universitas Syiah Kuala (USK), Agricultural Product Technology Department, Indonesia*

[3]*National Agency of Research and Innovation (BRIN), Biosistematic and Evolution Research Group, Indonesia*

[4]*Universitas Gadjah Mada (UGM), Faculty of Forestry, Indonesia*

[5]*HKBP Nommensen University North Sumatera, Fac. of Agriculture, Indonesia*

The genus *Pinus* is classified as one of the most widely distributed genera of conifer trees, with *P. merkusii* being the only member that grows naturally in the tropics including on the Sumatran island. Three native strains are known on Sumatra: Aceh, Kerinci, and Tapanuli, while the first one is known as the largest population among the three. Its resin is highly valued and classified as one of the most valuable Non Timber Forest Products (NTFP) worth up to US $ 50 million/ year. Pinus forests have played an immense role in maintaining the cool climate condition of the tropical highlands, however, their existence has been threatened due to massive planting of citron grass (*Cymbopogon* sp.) over the past two decades, due to its attractive selling price. Therefore, their genetic assessment at the DNA level is essential, before some of them may have disappeared due to massive deforestation. Simple sequence repeat (SSR) markers were applied to assess DNA variations due to its co-dominant, and effective characteristics. There were three to six SSR markers applied based on previous references, e.g. pm01, pm05, etc., whose lengths were varied from 100 to 3,000 base pair (bp). The DNA leaf samples from two distinct populations (low- & high-lands) were employed as material in this study. Thus, four accessions from Tapanuli, and three accessions from Kerinci were also applied as outgroup members. Gel electrophoreses was made in order to separate the bands, and band scoring was conducted via NTSYS programme, which calculated the bands based on similarity index. Finally, a dendrogram graph was produced in order to study further the phylogenetic among the samples. In general, there were five clades, with the majority of accessions (around 80 %) clustered in I, with an overall genetic distance calculated between 0.50 until 0.88.

Keywords: Biodiversity, conservation, DNA extraction, Gayo high lands, micro satellites

Borneo peat swamp forest and orangutan conservation in Central Kalimantan, Indonesia

Teresa Rojas Lara, Nina-Maria Gaiser

Borneo Orangutan Survival (BOS), Germany

Peatland restoration in Central Kalimantan and orangutan conservation are closely linked, as the destruction of peatlands in the region has had a devastating impact on the orangutan population. Central Kalimantan, located on the island of Borneo in Indonesia, is home to one of the world's largest areas of tropical peatland. Peatlands store vast amounts of carbon and support a unique array of species, including the critically endangered Bornean orangutan. However, over the past few decades, the peatlands have been extensively drained and converted into plantations, causing massive habitat loss, as well as contributing to climate change through the release of greenhouse gases. The Borneo Orangutan Survival Foundation (BOSF), the worldwide biggest primate conservation NGO, is actively involved in orangutan conservation and peatland restoration efforts. One of BOS' intervention areas is the Mawas protected forest, located within the ex-Mega Rice Project in Central Kalimantan. Mawas encompasses 309,000 hectares and is the home of 2,550 wild orangutans. Overall, peatland restoration in Central Kalimantan is crucial for the long-term survival of orangutans and other endangered species, as well as for mitigating climate change and promoting sustainable development in the region. This paper presents practical experiences and recommendations from the work of BOSF in cooperation with BOS Germany and local communities in Borneo in restoration of degraded peatlands, including paludiculture activities. Rewetting of degraded peatlands is achieved through canal blocking and reforestation with native species. Up to now BOS Germany has provided support to rewetting around 3.000 hectares of peatland and more than 280 hectares of degraded land have been reforested. All activities are carried out in close cooperation with local and indigenous communities and local authorities. Mawas has 53 villages with 29,000 families, of which a large percentage live below the poverty line. The principle of paludiculture, to restore the peat ecosystem while still paying attention to economic interests, is a sustainable option for these families. Agroforestry schemes with medicinal trees, sago, jelutung and fruit trees are being implemented, as well as beje aquaculture, a traditional and sustainable technique for breeding fish in artificial ponds in peatlands.

Keywords: Biodiversity, orangutan, paludiculture, peatland

Contact Address: Teresa Rojas Lara, Borneo Orangutan Survival (BOS), Rollbergstr. 28a, 12053 Berlin, Germany, e-mail: teresa.rojas@bos-deutschland.de

Trade-offs and synergy of the transition in crop-livestock-tree systems in northwest Vietnam

Thuy Dinh[1,3], Juliet Kariuki[1], Melanie Blanchard[2], Thi Thanh Huyen Le[3], Mizeck Chagunda[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*CIRAD, INRAE, Institut Agro, France*

[3]*Inst. of Animal Sci., Livestock Farming Systems and Environmental Res., Vietnam*

Northwest Vietnam has experienced changes in crop and livestock systems due to improved interventions of provincial programmes and different projects. These interventions can potentially change the performance of farms, the structure of farming systems, and their transition toward agroecology. However, the specific ways in which crop-livestock-tree farming systems may evolve towards agroecology in the presence of these interventions are not understood. The current study aimed to characterise the agroecological transition of crop-livestock-tree systems and identify the trade-offs and synergy on farm performance. The study was conducted in Northwest region of Vietnam in Chieng Chung commune, Son La province. A mixed methodology approach was used in this study in two steps. Group discussions with local stakeholders were first conducted to identify the main changes in the farm and key performance, which arise therefrom on farm performance. The key stakeholders included head of farmer organisation, women's organisation, communal leaders. In-depth interviews were conducted in sequence with 32 cattle-coffee farmers. These farmers were households who have adopted changes identified in the mentioned discussions. The transition in the farm was examined in three aspects of agroecology in terms of diversity, synergy, recycling, using TAPE tool developed by FAO, (2018). Socio-economic indicators were used, including productivity, revenue, production cost, quality of life, labour intensity, and job creation. Results show that land use in the farm has changed towards intensification and multifunctionality of coffee-based systems. Cattle systems have become more intensive in livestock density on farms and developing feeding systems. Interviewed farms have a transition in diversity (>50 %) due to the cultivation of new trees and improve grass species. The synergy between systems is also in transition (>=50 %) because of the increased use of manure for crop and trees, and crops and crop residues for animal feeds. However, recycling is still under agroecological transition (<50 %). In comparison to the past, the development has led to higher productivity in land and labour, increased revenue regularity, better quality of life in labour income, and more employment opportunities for local people. The transition has lowered chemical fertiliser cost (>70 %), while increasing labour hardship, especially for caring coffee systems

Keywords: Agroecological transition, synergy, trade-offs, Vietnam

Contact Address: Thuy Dinh, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 17, 70599 Stuttgart, Germany, e-mail: k.dinh@uni-hohenheim.de

Yield, labour use, and hybrid cocoa adoption in Ahafo Ano south-west district, Ghana

EMMANUEL TETTEH JUMPAH, TOMÁŠ RATINGER, MIROSLAVA BAVOROVÁ, BERNARD KWAMENA COBBINA ESSEL

Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Czech Republic

This study focused firstly on how hybrid cocoa affects yield and secondly on how access to labour affects the adoption of hybrid cocoa. Hybrid cocoa varieties are known to have better yields than traditional varieties. However, adoption of hybrid cocoa is extremely low and low cocoa yields remain a major challenge for cocoa production. To maximise the yield of hybrid cocoa, farmers need to weed, prune and apply agrochemicals in a timely manner. All this requires labour. Because of the low yields and low adoption of hybrid cocoa, this study aimed to investigate how farmers' yields are affected by the adoption of hybrid cocoa and how access to labour affects hybrid cocoa adoption. To do this, we collected household level data from 416 smallholder cocoa farmers in the Ahafo Ano South-West District of Ghana. We used a multistage sampling technique, purposive and simple random sampling, to collect the data. The ordinary least square (OLS) and seemingly unrelated regression (SUR) econometric estimation frameworks were used for the analysis. The SUR results showed that adoption of hybrid cocoa increased cocoa yield by $9.91 \, \mathrm{kg \, ha^{-1}}$ ($p < 0.01$). Access to labour increased adoption of hybrid cocoa by 1% ($p < 0.01$). We conclude that improved varieties such as hybrid cocoa are important in determining farmer productivity. In addition, access to labour improves the adoption of hybrid cocoa. Based on the results, we recommend agricultural extension programmes that raise awareness of the benefits of hybrid cocoa. Hybrid cocoa development programmes need to be strengthened to improve farmers' access to hybrid cocoa seedlings. Improved access to subsidised inputs such as fertilisers is needed to encourage adoption. Government and the private sector should support farmers with small-scale mechanisation equipment to reduce the use of human labour. All this will increase productivity, income and adoption of hybrid cocoa by smallholder cocoa farmers.

Keywords: Ghana, hybrid cocoa, labour, productivity, smallholder cocoa farmers

Contact Address: Emmanuel Tetteh Jumpah, Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Kamycka 129 Prague-Suchdol, 16500 Prague, Czech Republic, e-mail: jumpah@ftz.czu.cz

Farmer managed natural regeneration: Socioeconomic determinants and tree adoption patterns for smallholders in Kenya

Irene Awino Ojuok[1], Till Stellmacher[1], Ermias Betemariam[2], Tony Rinaudo[3], Michael Bollig[4], Christian Borgemeister[1]

[1]*University of Bonn, Center for Development Research (ZEF), Germany*
[2]*World Agroforestry (ICRAF-CIFOR), Kenya*
[3]*World Vision, Australia*
[4]*University of Cologne, Inst. for Social and Cultural Anthropology, Germany*

The problem of land degradation persists despite enormous efforts in sustainable land management. In Kenya, over 80% of the land is Arid and semi-arid hosting over 12 million people who live and depend on the degraded landscapes. Halting and reversing land degradation requires radical shifts in agricultural production systems that combine efforts against deforestation, climate change, and poverty. Farmer Managed Natural Regeneration (FMNR) has attracted global attention in the last 10 years as an adaptable farmer-led land restoration approach that can quickly transform degraded landscapes into productive land with optimum tree cover while strengthening the livelihoods of smallholders. Unlike the common direct tree planting, FMNR is about the systematic regeneration and management of already existing native trees, self-sown seeds, stumps, or wildings on the landscape. Despite the significant practical local success of FMNR in many parts of the world, there is limited scientific evidence on its suitability, potential, and limitations outside West Africa. Therefore, the growing global appetite for FMNR beyond West Africa must be augmented succinctly through applied and interdisciplinary empirical research for wider uptake. FMNR has been implemented in Baringo County, Kenya, since 2012 yet no empirical study conducted to establish differences between FMNR-practicing and non-FMNR-practicing households. Understanding household and farm characteristics differences between the two groups is key in determining the potential adoption drivers and their linkages to on-farm tree adoption patterns. This quantitative study compares household and farm characteristics of FMNR-practicing (n=145) and non-FMNR-practicing (n=143) farmers in Baringo County. Principal component analysis was used to establish household wealth status. Results indicate that higher wealth status, household size, education level (at least completion of primary education), and years of residence in the area (tenure security) are strongly associated with practicing FMNR. Female-headed Households are

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Contact Address: Irene Awino Ojuok, University of Bonn, Center for Development Research (ZEF), Ecology and Natural Resources Management, Genscherallee 3, Bonn, Germany, e-mail: barrackawino@yahoo.com

also more likely to practice FMNR compared to male-headed HH. The study also assesses perceived tree cover on farms. Findings suggest tree (native and non-native) species diversity and density are higher in FMNR-practicing HHs compared to non-practicing HHs. Non-practicing farmers have perceived a threefold decline in native trees over the last 5 years compared to FMNR-practicing farmers.

Keywords: Comparison, FMNR, practice, smallholders, socioeconomic determinants, tree adoption

Participatory development of bush control techniques to improve rangelands and food security in Borana, Ethiopia

Jaldesa Doyo[1], Pascale Waelti[2], Tabea Allen[2], Christoph Studer[2]

[1]*Oromia Agricultural Research Institute-Yabello Pastoral and Dryland Agriculture Research Center (YPDARC), Animal Feed and Rangeland Management, Ethiopia*

[2]*Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*

Bush encroachment is a major problem in the Borana rangelands, leading to suppression of the herbaceous biomass, and thus affecting livestock productivity and food security of pastoralists. One activity of the NRM-Borana project, implemented by a consortium of NGOs led by Helvetas, was to identify grazing areas for rehabilitation. Within this framework, a participatory research project (PAR) was undertaken by YPDARC and BFH-HAFL, to develop and test jointly with the local community innovative and effective methods to control bush encroachment.

In the areas selected for improvement, experimental sites of 6 to 12 ha were delimited. Different treatments were applied during dry season: Thinning plus base burning, thinning plus debarking plus burning, stand base burning plus not thinning, and enclosure plus no thinning (control). Data collection was conducted on 20*20 m sampling plots. The number of dead bushes was recorded at end of rainy season following the treatments. Herbaceous cover, composition and diversity were sampled from 0.5* 0.5 m quadrats in each corner and at the centre of the sampling plots. A participatory evaluation was conducted, collecting community perception through individual interviews and focus group discussions.

The two treatments including base burning (with or without thinning) were the most effective, killing over 90 % of the bushes, while the thinning plus debarking treatment killed 30 % of the bushes. Stand base burning was more effective on ground branched bush species such as: *Senegalia mellifera*, and *Vachellia drepanolobium*. Thinning the bushes had a positive effect on herbaceous basal cover and biomass production.

Thinning plus base burning was found to be very effective by communities in killing encroachers and regenerating grass cover, but more labour intensive than stand base burning alone. The thinning plus debarking technique was the least preferred because it was not effective in killing bushes and the workload was higher. The strong involvement of the beneficiaries into the problem identification, trial design, implementation and monitoring/evaluation were considered as success factors by the communities and the researchers. The inclusion of traditional knowledge led to effective and successful co-development of new techniques for bush control in Borana Lowlands.

Keywords: Bush encroachment, Ethiopia, invasive woody weeds, rangeland rehabilitation

Contact Address: Pascale Waelti, Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), 3052 Zollikofebt, Switzerland, e-mail: pascale.waelti@bfh.ch

Effects of pruning on workload and yields of native cacao under agroforests in Bolivia

Chigusa Keller[1], Johanna Rüegg[1], Consuelo Campos[2], Chloé Durot[1], Joachim Milz[2], Monika Schneider[1], Stéphane Saj[1]

[1]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*
[2]*Ecotop Foundation, Bolivia*

Cacao Nacional Boliviano (CNB) is the denomination for cacao derived from wild populations found in the Bolivian Amazon, traditionally collected by local communities. But cultivation surfaces are increasing as CNB beans are recognised internationally for their organoleptic qualities. So far, little selection has been done on the semi-wild populations cultivated and agricultural practices might have to be adapted to better support farmers' livelihoods.

We studied three different agricultural systems: CNB in agroforestry with bananas, fruit and timber trees with a management focusing on weeding and cacao pruning (AF); CNB planted in the cleared understory of a largely unmanaged secondary forest with (SFwP) or without (SFnP) cacao tree pruning. We monitored the yearly dry bean yield, labour time required for field activities, and resulting efficiencies of these three systems on plots established in 2012. Cacao was planted using CNB progenies from locally selected trees.

In all systems, the first cocoa pods matured 4 years after planting; production increased significantly in the 6th year and again between the 9th and 11th year. Cumulative dry yields in this third phase (2020-2022) were highest in SFnP (911.2 kg ha^{-1}), followed by AF (591.2 kg ha^{-1}) and SFwP (277.8 kg ha^{-1}). Heavy pruning was labour-intensive (up to 56% of total labour time) and limited yields but increased harvesting efficiency in the following years without pruning. In 2020-2022, harvesting in SFnP was 5 times more laborious as in SFwP and 2.7 times more as in AF, while its yield was only 3.3 and 1.5 times higher, respectively. Harvesting efficiency was thus higher in both pruned systems (AF: 7.3 kg workday^{-1}, SFwP: 6.7 kg WD^{-1}), compared to the unpruned system (4.4 kg WD^{-1}).

Our results underline the delicate balance between the practice of pruning, aiming at facilitating and concentrating the harvest at a limited height, and its effect on cacao physiology. Yet, association in AF shows that in completely managed systems, CNB is able to reach fair yield levels despite pruning. All in all, our results call for further domestication of CNB progenies aiming at earlier start of production, and adaptation of management practices (timing and intensity of pruning) for CNB.

Keywords: Bolivia, cacao agroforestry, native cacao, pruning

ID 550

The potential of tropical forage species maintained in the ILRI-forage-genebank for sustainable agriculture and food-security

Meki Shehabu Muktar[1], Alemayehu Teresssa Negawo[1], Alice Muchugi[1], Chris S. Jones[2]

[1]*International Livestock Research Institute (ILRI), Ethiopia*
[2]*International Livestock Research Institute (ILRI), Kenya*

The International Livestock Research Institute (ILRI) forage genebank, at Addis Abeba, Ethiopia, maintains a collection of 18,664 accessions of tropical forage germplasm, including species of leguminous fodder trees, herbaceous legumes, and forage grasses. The fodder tree species are a good source of high-quality, protein-rich forage for subsistence and commercial livestock production and supply foliage during dry periods when herbaceous species are not available. They can enhance the sustainability of farming systems because of their longevity, enhancement of fertility and physical stability in the landscape, they fit well in agroforestry systems and rehabilitation of degraded lands and offer opportunities for sustainable agriculture and intensification of tropical biodiversity. We have been characterising some of them, such as Sesbania sesban, to identify climate resilient, adaptive, and high biomass yielding genotypes that can be used as an alternative feed source in the dry season. The majority of the herbaceous legumes maintained in the genebank can be used for both human food and animal feed, however, most are underutilised and less characterised orphan crops. Currently we are working on some of them, including lablab (*Lablab purpureus*) and Cowpea (*Vigna unguiculata*). Improving the production and productivity of these underutilised crops is a promising strategy to diversify food systems. The perennial grasses maintained in the genebank also offer many beneficial characteristics. For instance, Napier grass, the most well-known tropical forage grass, is produced primarily as a fodder crop for animal feed because of its high feed quality, high dry matter content, and year-round availability. Given that it contains a lot of cellulose, which can be utilised as a source of carbon (energy), it has the potential to make biofuels, and is used in paper industry. In conclusion, we have been studying some species from each of these categories with the intent of tapping into the genetic diversity that sits in these crops, in order to better understand how we can support their improvement so that they can contribute to food and feed systems, soil health management, and rehabilitation of degraded lands. Some of the works will be presented in the seminar.

Keywords: Forage genebank, ILRI, perennial fodder tree, tropical forage

Contact Address: Meki Shehabu Muktar, International Livestock Research Institute (ILRI), Feed and Forage Development, Addis Ababa, Ethiopia, e-mail: mshehabu@gmail.com

Satellite remote sensing for above-ground biomass mapping of agroforestry plots: Enhancing income streams through carbon credits

Johannes Raher

Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Austria

Smallholder agriculture is an essential contributor to food security and income generation in many parts of the tropics. Agroforestry systems offer a unique opportunity for farmers to diversify their income streams by participating in carbon credit programs. However, monitoring above-ground biomass (AGB) and carbon stocks in these plots can be challenging and costly. Thus a narrative review was conducted of satellite remote sensing methods for assessing AGB on a plot level with the aim to reduce monitoring costs and enhance the feasibility of carbon projects. The review focused on sources from 2003 onwards to incorporate the latest technological advancements while excluding outdated satellite-based platforms. Various satellite remote sensing methods, including optical multispectral, hyperspectral, radar, and LiDAR techniques, were examined for their scope of application of plot-level AGB measurements.

Optical multispectral sensors, such as Landsat and Sentinel-2, provide valuable data for estimating AGB in these plots. However, precision and saturation issues need to be addressed. Higher-resolution optical data from commercial constellations such as RapidEye and Dove can offer more detailed information but may imply higher costs. The incorporation of Synthetic Aperture Radar (SAR) sensors, such as ALOS PAL-SAR and Sentinel-1, permits AGB estimation even in areas with persistent cloud cover, providing valuable insights into the agricultural landscape. LiDAR sensors, including ICESat-2 and GEDI, offer detailed information on the vertical distribution of AGB and can enhance precision in biomass mapping. Future missions, such as NASA's NISAR and ESA's BIOMASS, hold promise for improved SAR and LiDAR data.

Combined sensor optical data and LiDAR provide the most accurate results for AGB data at the plot level. Using only Landsat 8, the RMSE for AGB was 66 %, 50 % for LiDAR, and 49 % for a combination of Landsat 8 and LiDAR. This approach facilitates the establishment of cost-effective monitoring, reporting, and verification (MRV) systems, enabling effective participation in carbon offset programmes and enhancing the viability of plot-based carbon projects. By leveraging satellite remote sensing, farmers and local communities can engage in sustainable land management practices, diversify income streams through carbon credit programs, and contribute to climate change mitigation.

Keywords: Agro-forestry, remote sensing

Contact Address: Johannes Raher, Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Pfarrhofsberg 5, 4714 Meggenhofen, Austria, e-mail: johannes.raher@students.bfh.ch

Transforming degraded cacao plantations to fruit-rich 'food forests' with agroecology in the Peruvian Amazon

SIMON BOCK[1], ALEJANDRA ARCE[2], PHILIPP MENNIG[1], MANUEL NARJES[3]

[1]*Technical University of Munich, Agricultural Production and Resource Economics, Germany*
[2]*International Potato Center, Agroecology, Peru*
[3]*The Alliance of Bioversity International and CIAT, Colombia*

Smallholders of cacao plantations in the Amazonian region of Ucayali, Peru, are currently facing manifold economic, ecological, and social pressures. Evidence-based studies are required to support the restoration of their landscapes whilst meeting their food and market needs. This study aims to comprehensively understand smallholders' needs, challenges, and opportunities in terms of their production systems, food consumption, and markets.

Through the holistic lens of agroecology, it will provide insights as to how to best facilitate the transformation of these cacao plantations to biodiverse 'food forests' that integrate underutilized cultivated and forest species. The study uses a mixed-method approach that combines convergent and exploratory sequential mixed-method designs to capture the study's complexity and interdisciplinary nature. The approach consists of three main components:

1. Quantitative profiling of 20 farms by interviewing farmers and collecting geospatial data to provide an inventory of food produced and consumed (food profile).
2. Qualitative interviews with a subset of 10 farmers using semi-structured interviews to understand farmers' perceptions of their current food profile and potential expansion to biodiverse food forests.
3. Qualitative interviews with 5 potential customers or market experts to identify market opportunities and customer needs using purposive and snowball sampling.

The data analysis process includes:

- Bringing together qualitative data from farmer and market participant interviews through content analysis to identify perceptions of agroecological transformation and species that can support the transition.
- Merging identified species with quantitative data from part 1 using FarmDESIGN to generate farm configurations and trade-offs.
- Reflecting upon and evaluating the research results, identifying lessons learned and gaps for future research.

Contact Address: Simon Bock, Technical University of Munich, Agricultural Production and Resource Economics, Freisinger straße 52, 85417 Marzling, Germany, e-mail: simon.t.bock@tum.de

Anticipated outcomes involve a clear understanding of the primary needs of smallholder farmers in Ucayali and the prevailing market dynamics. A key outcome will be a tailored list of species that best support the transition to biodiverse food forests, based on the synergy of farmer insights and market trends.

In practice, the research will advocate for an agroecological transition to improve food and nutrition security. Importantly, this research places farmer knowledge at the center of the transformation process to ensure that solutions are both locally relevant and sustainable.

Keywords: Agroecology, agroforestry, amazon, cacao, FarmDESIGN, food forest, food system transformation, nutrition security, rainforest, sustainable development

Flood risk reduction nature-based solutions: potential forest restoration and agricultural land use in Búzi, Mozambique

Yamile Mariel Salame Villafani, Udo Nehren, Sabine Schlüter

TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics, Germany

Floods are increasing in frequency and severity in several parts of the world, mainly as a result of the effects of climate change and contextual conditions. They occur more intensively in the tropics and subtropics, where areas are mapped as risk zones with high vulnerability. This is the case of the study area: Mozambique, one of the poorest countries in the region and the world. Therefore, the application of nature-based solutions (NbS) presents an opportunity that can lead to the reduction of the intrinsic risks of floods by utilising and harnessing elements, services and processes of ecosystems. This research's primary focus is on analysing the potential of the implementation of the restoration of natural forests and floodplain and riparian woodland creation, a measure under the concept of NbS, as a way to reduce the risk of flood disaster in the district of Búzi in Mozambique. Furthermore, from the total area of the district, bare land and areas with sparse vegetation are presumed usable. These could contemplate transformation as part of interventions related to the NbS, including revegetation and providing suitable agricultural land. The study involves the evaluation of the potential of risk reduction through the application of on-site semi-structured and expert interviews, the analysis of assessment criteria, the processing of satellite imagery and field observation undertaken in various district localities. Results of this study showed that the restoration and creation of floodplain and riparian forests present a high potential to reduce the risk of flood disaster in the Búzi district through a number of provisioned ecosystem services and other co-benefits. Moreover, an area dedicated to production would expand as an intervention entailed in the measure. Consequently, an increase in production poses economic opportunities in the region, contributing, among other factors, to overall resilience.

Keywords: Agricultural land, flood risk, forests, nature-based solutions, resilience

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Contact Address: Yamile Mariel Salame Villafani, TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics, Robertstraße 2, 51105 Köln, Germany, e-mail: yamile.villafani@th-koeln.de

Biodiversity data as key to conservation of natural resources

Land-use impacts on biodiversity across spatial scales in a deforestation hotspot

Tobias Kuemmerle[1], Alfredo Romero-Muñoz[1], Julieta Decarre[1], Leandro Macchi[2]

[1]*Humboldt-Universität zu Berlin, Geography Department, Germany*
[2]*Instituto de Ecología Regional, CONICET, Argentina*

Tropical deforestation due to agricultural expansion is a major driver of the global biodiversity crises. Focusing on the understudied tropical dry forests of the South American Gran Chaco, a global deforestation hotspot, we highlight how biodiversity data is essential to understanding land-use impacts on the environment. We focused on larger mammals and birds as focal taxa and compiled a region-wide database of species' records from camera trapping (mammals) and point counts (birds). This allowed us to build models to quantify land-use impacts on biodiversity from local to regional scale and to identify landscape configurations that maintain biodiversity. Our results show that the expansion of agribusiness cropping and ranching has stark and negative impacts on biodiversity. Locally, we find populations of species to become depleted where land use expands and intensifies. Regionally, many species have lost major shares of suitable habitat (e.g., on average about 40 % for mammals). Across geographic scales, our analyses highlight the value of maintaining trees (local scale) and forest cover (landscape to regional scale), and we find strong evidence for critical thresholds of about 30–40 % tree/forest cover below which biodiversity meltdown occurs. This suggests a multi-scale strategy that fosters more biodiversity-friendly forms of agriculture locally (e.g., silvopastoral ranching systems), combined with landscape-level land-use planning that maintains larger patches of forest is needed to ensure the persistence of the Chaco's biodiversity. Tropical dry woodlands around the globe are under high and rising pressure. Unfortunately, biodiversity data is lacking for most of them. Our analyses show how rapid assessments of focal taxa can help predict biodiversity impact at scale, thus helping to mitigate biodiversity loss.

Keywords: Biodiversity, Gran Chaco, land-use change, South America, tropical dry forests and savannahs

Contact Address: Tobias Kuemmerle, Humboldt-Universität zu Berlin, Geography Department, Unter den Linden 6, 10099 Berlin, Germany, e-mail: tobias.kuemmerle@hu-berlin.de

Reconstructing past and predicting future biodiversity in (sub-) tropical forests by harnessing their archive function

Anja Linstädter, Magnus Dobler, Liana Kindermann

University of Potsdam, Inst. of Biochemistry and Biology, Biodiversity Research / Syst. Botany, Germany

Biodiversity data provides valuable information about species and habitats that exist in a particular ecosystem. This data helps conservationists to understand the functional relationships between different species and their habitats and to identify areas that are most in need of protection. Without accurate biodiversity data, it is thus difficult to make informed decisions about how to best protect and manage natural resources.

Measuring the status and trends of biodiversity is typically based on the assessment of a current condition relative to a previous condition or baseline. The ecological context for such an assessment is called a 'reference state'. However, a reference state is often challenging to quantify, or may even no longer be available in a contemporary ecosystem. This is also true for the woody vegetation in subtropical forests, woodlands and savannahs. Here, ecosystems are typically shaped by frequent natural disturbances such as wildfire and herbivory. In the past decades to centuries, the structure, composition and diversity of woody vegetation have often been massively altered by humans - either by direct human impact such as selective logging or by indirect human impact such as changes to the frequency and intensity of natural disturbances. These novel disturbance regimes may have detrimental consequences for biodiversity and natural resources, which are difficult to quantify without a proper reference state.

Here we argue that harnessing the archive function of individual trees and woody plant communities can complement or even replace the reference state approach. Based on large inventories collected along steep disturbance gradients in southern African savannahs and woodlands, we introduce a new method specifically designed to quantify disturbance impacts on tree individuals and whole stands. We contrast our results to those gained with a reference state approach. In a second step, we harness the demographic structure of woody vegetation to reconstruct temporal biodiversity changes from the past until today, and to project future changes. Our approach to generating temporal trends in biodiversity from snapshot data is also useful to inform conservation policies and management strategies.

Keywords: Biodiversity data, disturbance regime, savannahs

Widespread declines of formerly abundant species drive insect loss

Roel van Klink[1], Diana Bowler[2], Jonathan Chase[1]

[1]*German Centre for Integrative Biodiversity Research, Dept. of Biodiversity Synthesis, Germany*

[2]*Centre for Ecology and Hydrology, United Kingdom*

Our human lives are intricately entwined with those of insects, as we rely on them for crop pollination and decomposition, while other insects are among our most feared crop pests and disease vectors. Yet, we know close to nothing about the status and trends of most insect species.

But what we do know is reason for concern. Using meta-analytical methods, we have previously shown that declines of terrestrial insect abundances are widespread. What remains unclear, however, is whether other aspects of biodiversity, such as species numbers, evenness and relative abundances, are also changing. We compiled long-term insect monitoring data to study global patterns of insect biodiversity change. We found that despite declines in abundances, there is only a small loss in local species numbers, whereas evenness is increasing. These contrasting patterns can be explained by disproportionate declines of dominant species and high rates of species replacement of rare species. The loss of formerly common species can explain declines in insect abundances. Given the ecological importance of dominant species, their disproportionate declines have probably already led to the widespread rewiring of food webs and changes in ecosystem functioning and services.

To do a better job of identifying such alarming levels of biodiversity loss in the future, we need new, standardised monitoring programs. Fortunately, technological advances will soon allow us to upscale insect monitoring to unprecedented levels of taxonomic and spatial coverage. DNA barcoding, computer vision, automated acoustic surveys, lidar and radar may be drawn upon to enhance ecological research and monitoring for insect conservation.

Keywords: Biodiversity loss, insects, long-term, monitoring

Contact Address: Roel van Klink, German Centre for Integrative Biodiversity Research, Department of Biodiversity Synthesis, Puschstrasse 4, 04229 Leipzig, Germany, e-mail: roel.klink@idiv.de

Reducing the taxon bias in biodiversity data using robots, nanopore sequencing, and Ai identification tools for arthropods

Rudolf Meier[1], Lorenz Wührl[2], Christian Pylatiuk[2]

[1]*Museum fuer Naturkunde Berlin, Germany*

[2]*Karlsruhe Institute of Technology, Inst. for Automation and Applied Informatics (IAI), Germany*

Biodiversity science neglects hyperdiverse arthropod clades despite their importance with regard to terrestrial biomass, species diversity, and ecosystem services. In the talk, I will first document that more than half of the flying insect diversity in Malaise trap samples is concentrated in 20 family-level clades regardless of where the samples were collected. I then demonstrate how little we know about most of these arthropods clades by comparing the species richness in quantitative samples with the number of described species. This leads to the conclusion that we need new techniques for these taxa. At the Center for Integrative Biodiversity Discovery of the Natural History Museum in Berlin we have collaborated with colleagues from the Karlsruhe Institute of Technology to develop a robot ('DiversityScanner') for tackling abundance and efficient DNA barcoding techniques for tackling species richness. The DiversityScanner detects, images, and measures individual specimens before they are placed into microplates for barcoding with rapid and cost-effective techniques involving Nanopore sequencers. After assigning images to species based on DNA barcodes, we can start to train Convolutional neural networks (CNNs) for all taxa with more than 100 images. The goal is delivering AI tools for large numbers of common species so that they become identifiable for everyone based on images. The power of the approach will be discussed for a few examples from tropical and non-tropical environments. One goal is to dramatically increase the number of species that can be described and make all the new species identifiable via a range of different techniques.

Keywords: Biodiversity

Invertebrate-derived dna (iDNA) as a source for vertebrate biodiversity and disease monitoring

Camila Mazzoni

Leibniz Institute for Zoo and Wildlife Research, Evolutionary Genetics, Germany

The use of invertebrates as a source of vertebrate DNA (iDNA) has emerged as a powerful tool for monitoring biodiversity. iDNA can be used to generate barcodes that identify local fauna, and various invertebrates such as hematophagous, saprophagous, and coprophagous species can provide vertebrate material. Mosquitoes and carrion flies are among the most ubiquitous taxa and are easily found in different environments and climates. In this presentation, I will share results from several studies that explore the potential of iDNA in ecological and evolutionary studies involving vertebrate species and populations. These include 1) a comparison between mosquitoes and carrion flies in detecting vertebrate fauna in a semi-urban environment, where the the use of flies in the detection of wildlife in a suburban environment showed to be more effective in terms of collection of samples and detection of vertebrates, 2) the analysis of fly diversity across a gradient of urbanisation, where the abundance of flies was shown to decline with urbanisation, although several species remained highly abundant across the urban gradient, 3) the analysis of vertebrate DNA carried by flies in urban, rural, and forest areas, which detected the mammal assemblage in forest or rural habitats to be dominated by non-domestic animals while the urbanised environment is characterised mainly by human and domestic animals, and 4) the assembly of mitochondrial genomes of different vertebrate species from invertebrate sources such as leeches and flies using taxon-specific DNA capture. In this study, sixty percent of the iDNA extracts allowed for the recovery of (near) complete mammalian mitochondrial genomes that could be used for phylogenomic analyses. Looking ahead, future perspectives include the possibility of using iDNA to associate host-vector and host-carrier for diseases that cross species boundaries.

Keywords: Biodiversity, iDNA, invertebrates, vertebrates

Contact Address: Camila Mazzoni, Leibniz Institute for Zoo and Wildlife Research, Evolutionary Genetics, Alfre-Kowalke-Strasse 17, 10315 Berlin, Germany, e-mail: mazzoni@izw-berlin.de

ID 407

An insect-based biodiversity metric for agroecological systems in Africa

Tobias Landmann, Faith Ashiono, Henri E.Z. Tonnang

International Centre of Insect Physiology and Ecology (icipe), Kenya

Land degradation, pesticides and monoculture within agro-ecological systems can adversely affect insect biodiversity and result in insect pollinator species declines. As over 50 % of crops in Africa, specifically, are pollinator dependent, losses in pollinator abundance can negatively affect crop yields and food security. Moreover, the post-2000 Global Biodiversity Conservation (GBC) Framework of the UN requires countries to report on targets that include species or ecosystem-specific biodiversity status information. The GBC and other political frameworks require that localised biodiversity patterns are considered and the establishment of biodiversity status baselines. In this work, an easy to implement and spatial explicit (localised) insect biodiversity baseline metrics is introduced. The metric relies on readily available earth observation (EO) data and insect species data, collated from citizen science platforms, such as the iNaturalist. Butterflies, moths, and rove beetle species data were used as these groupings represent indicator species for overall ecosystem intactness. Specifically, the EO data was used together with the insect species data to predict species richness. Secondly, high resolution (10-meter resolution) EO data is used to heuristically predict the degree of per pixel human impact, or landscape naturalness. The two variables (species richness and naturalness) were then augmented to produce (beta-) biodiversity status estimates over wider areas in Africa. We found that data density of the occurrence data is a key limitation to scaling the method to the whole of Africa, thus only 6 % of the total surface area in Africa could be modelled. Localised results for Kakamega in Kenya and the St. Lucia region in South Africa were highlighted and discussed. In both areas, natural forests, gallery forests and wetlands, within highly transformed agro-ecological landscapes, exhibited the highest biodiversity status. This underlines the roles of these ecosystems as maintainers of biodiversity and important habitats for pollinators that help to sustain crop yields. The developed metric is applicable now and amendable once more insect data becomes available (from citizen science). The model we used is straightforward (well understood) and accurate, thus easy to understand and utilise by policy makers.

Keywords: Africa, biodiversity indicator, citizen science, insects, remote sensing

Contact Address: Tobias Landmann, International Centre of Insect Physiology and Ecology (icipe), Icipe str.1, 00100 Nairobi, Kenya, e-mail: tlandmann@icipe.org

Invasive alien species invading our health in Kenya

Tasneem Osman[1], Eric Fèvre[2], Christian Borgemeister[1]

[1]*University of Bonn, Center for Development Research (ZEF), Germany*
[2]*University of Liverpool, Inst. of Infection, Veterin. and Ecological Sci., United Kingdom*

Invasive alien plant species threaten the integrity of ecosystems throughout the world. They affect not only the species diversity of native ecosystems but also threaten their biological integrity. Due to the increase in the movement of people and goods around the world and with new trade routes opening and enhanced transportation, the number of species being introduced into new areas is rising. Currently, the spread of invasive plant species is a major problem in Kenya, where the replacement of indigenous flora. They reduce agricultural yields, irrigated croplands, grazing areas, water availability, and contribute to the spread of vector-borne diseases.

A particular example of invasive plant is *Parthenium hysterophorus* (Asteraceae). Native to the subtropics and tropics of North and South America, the weed has negative effects on human, livestock, agriculture and the environment. The study notes that the weed is one of the world's most serious invasive plants that are able to thrive and spread aggressively outside its original geographical areas.

The aim of this study is to determine the abundance and diversity of mosquito vectors at sites with different degrees of invasive plant infestations in the Rift valley area in Kenya. The study sites are located in Baringo county, which lies between latitudes 0° 12 and 1° 36 N and longitudes 35° 36 and 36° 30 E. Mosquitoes were captured using a combination of different trapping techniques from six sites three of them with Invasive species; *Parthenium* and three without Parthenium. 48 species were identified. The survey was conducted to assess mosquito abundance and diversity in selected areas, which might provide beneficial knowledge for targeted control.

The findings of the study will be expected to have an inventory of the mosquito population composition and of the abundance and richness of arboviruses. Further gain insight into how changes in community ecology interact with the main types of land-use change and influence the dynamics of relevant arboviruses in Kenya.

Keywords: Agricultural expansion, agricultural intensification, arboviral disease vectors, invasive plants, land-use changes, mosquito ecology, *Parthenium hysterophorus*, pathogen transmission

Contact Address: Tasneem Osman, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: tasneemmoawia@hotmail.com

Animals and livestock systems

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The role of livestock production systems in food systems transformation

Posters

Online posters

Efficacy of two anthelmintics against gastrointestinal nematodes of sheep in the silvopastoral zone of Senegal, Mali and Burkina Faso

Mamadou Coulibaly[1], Aminata Beye[2], Linda Cletchio Gabriella Traoré[3], Regina Roessler[4], Hawa Coulibaly[1], Drissa Coulibaly[1], Tamsir Mbaye[5], Marième Fall Ba[5], Hadja Sanon[6], Sita Sanou[6], Eva Schlecht[7], Felix Heckendorn[8]

[1]*Inst. Polytechnique Rurale / de Formation et de Recherche Appliquée (IPR/IFRA) /Institut d'Economie Rurale, Breeding Science and Technology / Cattle Program, Mali*

[2]*Cheikh Anta DIOP University, Senegalese Inst. of Agricultural Research, Dept. of Plant Biology (FST/UCAD), Senegal*

[3]*Nazi Bony University (UNB), Dept. of Animal Prod. Syst. (SNA/SPA), Burkina Faso*

[4]*University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany*

[5]*Senegalese Inst. for Agric. Res. (ISRA), National Forestry Research Centre (CNRF), Senegal*

[6]*Inst. of Environment and Agricultural Research (INERA), Dept. of Animal Productions, Burkina Faso*

[7]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

[8]*Research Inst. of Organic Agriculture (FiBL), Animal Science Dept., Switzerland*

Gastrointestinal nematodes (GIN) are a major impediment to sheep health and productivity. Frequent use and under dosing of chemical anthelmintics (AH) have led to the development of GIN populations which are resistant to these drugs in many parts of the world. In West Africa, the importance of GIN infections in sheep is poorly documented and the potential problem of AH resistance is neglected.

We therefore conducted an on-farm study to determine the efficacy of two AH (Albendazole and Ivermectine) that are frequently used in Mali, Burkina Faso and Senegal, the focal countries of the EU-funded project SustainSahel. Sheep carrying natural GIN infections were selected from another study on GIN prevalence and infestation intensity. In each country, 24 male sheep with a minimum faecal egg count of 500 eggs per gram were selected for the efficacy study. Sheep were randomly allocated to 3 treatment groups of 8 animals: Ivomec® (Ivermectin), Valbazen® (Albendazole), and Control (without treatment). AH doses were administered according to the manufacturers' instructions after weighing the animals, namely Valbazen (oral) at $7.5\,\mathrm{mg\,kg^{-1}}$ body weight, Ivomec (subcutaneous) at $0.2\,\mathrm{mg\,kg^{-1}}$ body weight. The faecal

egg count reduction test (FECRT), as recommended by World Association for the Advancement of Veterinary Parasitology, was used to determine anthelmintic efficacy. For Ivomec®, FECR were 97 %, 95 % confidence interval (CI) (89%-100 %); 97 %, CI (93%-99 %) and 56 %, CI (24%-76 %) in Burkina Faso, Mali and Senegal, respectively. These results point to AH resistance of GIN to Ivermectin in Burkina Faso and confirm resistance to this drug in Senegal. In Mali, however, ivermectin did not show reduced efficacy. For Valbazen®, FECR were 99 %, 95 % CI (96%-100 %); 100 %, CI (99%-100 %) and 75 %, CI (43%-90 %) in Burkina Faso, Mali and Senegal, respectively. This corresponds to full efficacy of Albendazol in Mali and Burkina Faso and AH resistance in Senegal.

We conclude that GIN resistance to both anthelmintics is present in the study region. The use of alternative treatment options, such as by secondary plant metabolites, could be a future control option to reduce the progress of resistance towards allopathic anthelmintics.

Keywords: Anthelmintic efficacy, faecal egg count reduction test, gastrointestinal nematodes, West Africa.

Yellow mealworm as a protein alternative for lactating rabbit does

Tolulope Aremu[1], Zdenek Volek[2], Tersia Needham[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriScience, Dept. of Animal Sciences and Food Processing, Czech Republic*

[2]*Inst. of Animal Science, Dept. of Nutritional Physiology and Animal Product Quality, Czech Republic*

Insects as a sustainable alternative protein source for human food and animal feed has received much attention of late, with benefits cited including their prolificacy, high feed conversion of typically waste materials, low land requirements etc. During period of high nutritional demand, such as lactation, good quality feedstuffs are necessary for livestock. Hence, this study determined the effect of the substitution of soybean meal with yellow mealworm (Tenebrio molitor) meal on the milk yield of lactating rabbits. A total of 24 individually housed Hyplus rabbit does were divided into two treatment groups fed pelleted diets of either typical soybean-based diet (SBM; n = 13) or a 10 % inclusion rate of insect yellow mealworm meal (IM; n = 11) during a lactation period of 32 days. Diets were formulated for the same nutritional composition. Does were balanced through the initial experimental design for parturition number and litter sizes at birth were corrected to 10 kits per doe utilising cross-fostering. Data were analysed using the VEPAC procedure in Statistica. Diet (SBM vs. IM) and day of lactation were included as fixed effects and animal nested in treatment was included as a random effect. Weight on the day of parturition (after parturition) was included as a covariate. Data was tested, and confirmed, for normality. The level of significance used was $p < 0.05$ throughout. No significant differences were found for the interaction for diet and days of lactation for milk yield ($p = 0.990$). The main effect of diet did not influence the milk yield ($p = 0.775$). The main effect of day of lactation was significant ($p < 0.0001$), showing a rapid increase in milk production until day 13 of the experiment, where after it plateaued, and started to decrease from day 19 of the experiment. In conclusion, the IM diet was equally as effective as the SBM in supporting milk production in rabbit does.

Keywords: Hyplus, insect yellow mealworm meal, lactating rabbits, milk yield

Contact Address: Tolulope Aremu, Czech University of Life Sciences Prague, Fac. of Tropical AgriScience, Dept. of Animal Sciences and Food Processing, 16500 Praha 06, Czech Republic, e-mail: aremu@ftz.czu.cz

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Redefining frameworks for animal welfare, ethics, and trade-offs in non-conventional livestock species production: The case of Cameroon

Maria Oguche[1], Kerstin Schopp[2], Juliet Kariuki[1], Thomas Potthast[2], Glory Shemlon[1], Jaurès Simo Kouam[3], Kingsley Etchu[4], Ursule Mekongo[5], Alexis Teguia[3], Aziwo Tatanja Niba[6], Félix Meutchieye[3], Mizeck Chagunda[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*Eberhard Karls Universität Tübingen, Germany*

[3]*University of Dschang, Cameroon*

[4]*The Institute of Agricultural Research for Development (IRAD), Cameroon*

[5]*Livestock Extension Cooperative, Cameroon*

[6]*University of Bamenda, Cameroon*

Non-conventional livestock species including Giant African Land snails, Cavies, Grasscutters, and Guinea fowls contribute to a steadily rising percentage of West-Central Africa's population's diet. Despite their importance, their consumption is not uncritical from a sustainability and ethics perspective. Scanty empirical evidence exists regarding trade-offs in their value-chain, risks like zoonosis in their consumption as well as animal welfare issues. Poor understanding of animal husbandry practices for these species further raises concerns about animal welfare and ethics. Given these knowledge and discourse gaps, a multi-stakeholder symposium was held at the University of Dschang, Cameroon which connected leading experts on non-conventional livestock species. The aim was to create a forum for stakeholders to exchange knowledge and discuss research gaps in relation to developing a framework for sustainable production of non-convectional livestock species. A World Café approach was used to facilitate these discussions with 35 multidisciplinary participants from academia, policy makers, farmers and students. Insights on the contribution of the non-conventional livestock species to biodiversity and sustainable conflict-resilient food systems were discussed. For example, the Giant African Land snail are mostly obtained from the wild with implications for upholding the integrity of future wild populations. A three-pronged approach was proposed. Firstly, the need to understand local contexts to support and/or establish compatible and workable principles of animal welfare and ethics (local - micro). Secondly, the need for implementation, enforcement and revision of already existing policies and institutions guiding the production of non-conventional livestock species (national – macro). Thirdly,

promoting the role of academia to address research gaps and strengthen collaboration with extension (and other) agencies to disseminate knowledge and minimise the gap between researchers and farmers (intermediary – data). The outcomes described in this study begin to highlight the importance of creating an enabling framework which minimises the trade-offs and risks of disease infection; promotes better animal welfare practices for improved quality of products and responds to the needs for non-conventional livestock species (to be renamed) without undermining ethical principles that support sustainable development.

Keywords: Cameroon, emerging systems, ethics, food insecurity, non-conventional livestock, welfare

Assessing the feasibility of applying the welfare quality® assessment protocol for dairy cows on farms in Kiruhura District, Uganda

Paul Ssuna

Animal Welfare Competence Center for Africa, Animal Welfare, Uganda

Welfare Quality® assessment protocols have been used extensively in Europe to assess welfare of livestock for research or policy objectives, however, their applicability to production systems in Uganda has not been examined. The aim of this research was to assess the feasibility of applying the welfare quality® assessment protocol (designed for production systems in the European Union) for dairy cows on extensive farms in Kiruhura District, Uganda. In this study, the protocol was tested on 24 dairy farms (herd sizes ranged from 15 to 125 cows) randomly selected from 6 sub counties in Kiruhura district over two visits. The first visit was early in the morning (6:30 am) during milking and another in the afternoon (2:00 pm) during grazing. Each of the assessments lasted for about an hour. The visit in the morning included a questionnaire-guided interview to evaluate the care, management and health, and animal welfare attributes of the cows when they were still in the ban. The second visit in the afternoon assessed farm resources, stockman ship and environment in which the cows graze. Overall, 1256 cows were assessed and 24 farm managers interviewed. The assessment captured measures to be retained without modification (for example assessing absence of hunger by using rumen fill score or body condition score), measures retained with slight modification (for example when assessing absence of prolonged thirst, the method of assessment was modified from 'How far animals must walk to access water?' to 'Does the farm have a watering point?') and eliminating unsuitable measures (for example assessing baulking, running and stumbling could not be assessed because animals move in large open spaces). The study showed that not all measures are feasible for on-farm assessment among extensive dairy farms in Kiruhura, district, Uganda as only 27 measures were found practical. Therefore, adaptation of existing protocols and setting of acceptable and non-acceptable thresholds tailored to local production systems for each of the identified measures are necessary to enhance adoption of the existing protocol.

Keywords: Extensive dairy production systems, feasibility, Uganda, welfare quality assessment protocol

Contact Address: Paul Ssuna, Animal Welfare Competence Center for Africa, Animal Welfare, Livingstone drive covab veterinary complex, 7062 Kampala, Uganda, e-mail: ssunapaul57@gmail.com

Co-integrated panel models to estimate relationships between cattle and greenhouse gas emissions for Latin America

Danny Fernando Sandoval, John Jairo Junca Paredes, Karen Enciso, Manuel Díaz, Aura Bravo, Stefan Burkart

The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia

The cattle sector is key to the economy of several Latin American countries, however, it strongly contributes to environmental degradation through the emission of greenhouse gases and deforestation, among others. The objective of this study is to analyse the long- and short-term relationships of variables such as population growth, expansion of pastureland, and deforestation with cattle greenhouse gas emissions and beef and dairy production for 15 Latin American countries. Using information consolidated by FAOSTAT for the period between 1990–2019, a cointegrated panel method (Pooled Median Group) was applied, with which six specifications were estimated. The main results show that, in the long-term, a population growth of 1 % decreases methane emissions derived from manure management in beef production by 1.41 % and increases those derived from enteric fermentation by 0.97 %. Likewise, a 1 % expansion of pastureland increases methane emissions from manure management by 2.66 % and decreases those related to enteric fermentation by 2.15 %. The results indicate that at the aggregate level for the region there is evidence of stable long-term relations. This means that the effects population growth, the expansion of pastureland, and deforestation have on greenhouse gas emissions from cattle production tend to decrease over time. This long-term behaviour may be marked by those countries that have a more developed cattle sector, aimed at reducing the impacts of cattle production on the environment, for example, by supporting the adoption of improved forage technologies, silvo-pastoral systems, grazing management practices, and regulatory frameworks and incentives. The cattle sector of these countries can be used as a regional benchmark and its lessons learned as inputs for sustainable intensification processes in countries with a developing cattle sector.

Keywords: Cattle, co-integration, deforestation, greenhouse gas emissions, pooled median group, sustainability

Investigation on *in vitro* nutritive values and *in vitro* methane production of different tree legume forages available in the campus of the university of veterinary science, Yezin, Myanmar

Aung Aung, Ulrich Kuch

Goethe University, Frankfurt, Institute of Social Medicine, Occupational Medicine and Environmental Medicine, Germany

By feeding on feedstuffs that cannot be used for monogastrics and human beings, ruminants can convert such plant matter to meat, milk, hide, etc. The major feed for ruminants in tropical developing countries is roughages with low quality nutritive values. To meet the requirement of the animals, it is necessary to improve the nutritive values of roughages by various methods such as physical treatment, chemical treatments and supplementation with concentrates. Protein rich tree legumes are alternative supplements to replace for concentrates. Nowadays, climate smart livestock systems are an important issue, because ruminants emit methane from enteric fermentation. It is noticeable not only on *in vitro* methane production, but also on *in vitro* nutritive values as important information for the mitigation of methane emission from ruminants. We thus conducted an experiment with the aim to investigate the *in vitro* nutritive values and *in vitro* methane production of tree legume forages collected from the campus of the University of Veterinary Science in Yezin, Myanmar. Forages of four tree legumes, *Albezia saman*, *Albizia procera*, *Leucaena leucocephala* and *Gliricidia sepium* were amassed for use as experimental feedstuffs in a completely randomised design with four replicates. The Hohenheimer Futtermittel-Test was applied for *in vitro* methane measurement and *in vitro* nutritive values. Of these feedstuffs, *Leucaena* leaves had the highest dry matter digestibility, organic matter digestibility, dry matter intake and metabolisable energy all significantly higher than those of the others ($p < 0.05$). In the aspect of total gas at 24 hours incubation time, *Leucaena* and *Gliricidia* had significantly higher amounts than the rest of the feedstuffs while no significant difference in methane concentration was observed. According to these findings, *Leucaena* gave more satisfactory results than others because it had higher *in vitro* nutritive values and the same amount of methane concentration compared with the other tree legume forages.

Keywords: *In vitro*, *in vivo*, methane, tree foliages

Contact Address: Aung Aung, Goethe University, Frankfurt, Institute of Socail Medicine, Occupational Medicine and Environmental Medicine, Hölderlinstraße, 65779 65779/ Kelkheim, Germany, e-mail: aung@med.uni-frankfurt.de

Use of trees and shrub by farmers to control gastrointestinal nematodes (GIN) in extensive livestock production systems of West Africa

AMINATA BEYE[1], LINDA CLETCHIO GABRIELLA TRAORÉ[2], MAMADOU COULIBALY[3], TAMSIR MBAYE[4], EVA SCHLECHT[5], MARIÈME FALL BA[4], DAOUDA NGOM[1], FELIX HECKENDORN[6], REGINA ROESSLER[7], HADJA SANON[2], DRISSA COULIBALY[3], HAWA COULIBALY[3], SITA SANOU[2], ASSAN G. FALL[8]

[1]*Cheikh Anta DIOP University, Senegalese Inst. of Agricultural Research, Dept. of Plant Biology (FST/UCAD), Senegal*

[2]*Nazi Bony University (UNB), Dept. of Animal Prod. Syst. (SNA/SPA), Burkina Faso*

[3]*Inst. Polytechnique Rurale / de Formation et de Recherche Appliquée (IPR/IFRA) /Institut d'Economie Rurale, Breeding Science and Technology / Cattle Program, Mali*

[4]*Senegalese Inst. for Agric. Res. (ISRA), National Forestry Research Centre (CNRF), Senegal*

[5]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

[6]*Research Inst. of Organic Agriculture (FiBL), Animal Science Dept., Switzerland*

[7]*University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany*

[8]*Senegalese Institute of Agricultural Research, Senegal*

Traditional veterinary practices have taken a back seat to modern veterinary medicine in livestock health management in Africa. However, the latter is not able to cope with all health problems on livestock farms, especially in rural areas where access to quality veterinary drugs and services is not available. Adding to this is the low purchasing power of livestock farmers. They are forced to resort to traditional practices to treat their animals in case of disease, which is especially true for gastrointestinal nematodes (GIN) in small ruminants.

This study aimed to identify, with the herders, the local woody plant species usually used to treat parasitic infections of small ruminants in West Africa. Indeed, in traditional medicine, woody species represent about 65 % of the most important African medicinal plants. An ethno-botanical survey based on semi-structured interviews was conducted with 370 herders and agro-pastoralists in Senegal, Mali and Burkina Faso between June and July 2021. More than 60 % of the respondents stated that the use of tree-based remedies has a positive impact on animal health. Out of 81 herders surveyed in Senegal, 42.0 % used woody plants for animal health treatment. In Burkina Faso, 28.7 % out of 159 farmers used ligneous plants to treat their animals

Contact Address: Aminata Beye, Cheikh Anta DIOP University, Senegalese Inst. of Agricultural Research, Dept. of Plant Biology (FST/UCAD), Dakar, Senegal, e-mail: aminabeye45@gmail.com

against gastrointestinal strongyles. In Mali, 16.4 % out of 130 farmers used parts of trees to treat small ruminants against GIN. Across the three countries, 20 woody species belonging to 10 botanical families were identified as being regularly used to treat GIN. *Khaya senegalensis*, *Azadirachta indica* and *Faidherbia albida* were the most commonly cited species, and at family level Fabaceae (67 %) dominated before Meliaceae (17 %) and Combretaceae (17 %). Leaves (50 %), pods (33 %) and bark (17 %) were the organs mainly used to produce herbal anthelmintics. The cross-country comparison of results revealed that, although farmers have a good knowledge of effective plant-based GIN control, preparation formulae and application doses are often variable and only mastered by a few users. In view of smallholders' reliance on herbal medicine, more effort should be devoted to tap the potential of woody plants as alternative remedies for the treatment of GIN in sheep and goats.

Keywords: Gastrointestinal nematodes, small ruminants, West Africa, woody plant species

Transforming beef farming systems: advances in grazing management for sustainable production

Ricardo Gonzalez Quintero[1], Liliana Atencio Solano[2], Emiro Suárez Paternina[2], Jorge Mejía Luquez[2], Jesús Fernando Florez[3], Stefan Burkart[4], Jacobo Arango[4]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Kenya*
[2]*Corporacion Colombiana de Investigacion Agropecuaria (AGROSAVIA), Colombia*
[3]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*

This study analyses the impact of high-quality nutritional grasses in feeding on beef cattle in farms from Córdoba Department, Colombia. The low productivity and high environmental impact associated with beef farming in the region make it necessary to implement sustainable intensification strategies that increase animal yield and mitigate climate change. The study uses the life cycle assessment (LCA) methodology to estimate the carbon footprint (CF) of 20 beef fattening farms in Cordoba Department, estimates the economic valuation of the CF, and identifies the potential beef yield improvements and GHGE mitigation in farms that have implemented high-yield improved pastures. The CF was calculated in a cradle-to-farm gate perspective. GHGE were estimated by applying the 2019 Refinement to 2006 IPCC guidelines. One kg live weight gain (LWG) corresponded to the functional unit. No allocation was made as the only product leaving the farm was live animals. The market price method was applied for the economic valuation of CF. The results of the study show that the 25 % of farms with the lowest CF (varying from 9.2 and 12.1 $kgCO_2$-eq $kgLWG^{-1}$) have an average live weight gain (LWG) of 349.2 kg $AU^{-1}yr^{-1}$, and their CF is valued at US\$0.32. All the farm areas correspond to high-yield improved pastures, and good cattle and pasture management practices are implemented. On the other hand, the remaining 75 % of farms have a CF between 13.5 and 43.4 $kgCO_2$-eq $kgLWG^{-1}$, a meat yield of 210 kg LWG $AU^{-1}yr^{-1}$, less than 50 % of farm area dedicated to improved pastures, poor cattle and pasture management practices, and their CF is valued at US\$0.64. The study highlights the importance of a nutritious cattle diet, through the adoption of high-yield improved pastures, and good managing practices in improving animal productivity, environmental performance, and economic valuation of the CF of beef cattle systems. The findings provide insights into possible technological and managerial changes for transforming beef cattle systems in Colombia by enhancing animal productivity and mitigating GHGE. In conclusion, the adoption of high productivity and quality nutritional grasses in beef cattle feeding can be a sustainable strategy to enhance yields while mitigating GHGE.

Keywords: Carbon footprint, economic assessments, greenhouse gas emissions, life cycle assessment, mitigation actions

ID 405

Prevalence and intensity of gastrointestinal nematode infection in small ruminants in three West African countries

Linda Cletchio Gabriella Traoré[1], Mamadou Coulibaly[2], Aminata Beye[3], Felix Heckendorn[4], H. Oumou Sanon[5], Sita Sanou[5], Hawa Coulibaly[2], Drissa Coulibaly[2], Tamsir Mbaye[6], Marième Fall Ba[6], Eva Schlecht[7], Regina Roessler[8]

[1]*Nazi Bony University (UNB), Dept. of Animal Prod. Syst. (SNA/SPA), Burkina Faso*
[2]*Inst. Polytechnique Rurale / de Formation et de Recherche Appliquée (IPR/IFRA) /Institut d'Economie Rurale, Breeding Science and Technology / Cattle Program, Mali*
[3]*Cheikh Anta DIOP University, Senegalese Inst. of Agricultural Research, Dept. of Plant Biology (FST/UCAD), Senegal*
[4]*Research Inst. of Organic Agriculture (FiBL), Animal Science Dept., Switzerland*
[5]*Institute of Environment and Agricultural Research (INERA), Dept. of Animal Production, Burkina Faso*
[6]*Senegalese Inst. for Agric. Res. (ISRA), National Forestry Research Centre (CNRF), Senegal*
[7]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*
[8]*University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany*

This study was carried out to provide missing information on the prevalence and intensity of gastrointestinal nematode (GIN) infections of small ruminants in three West African countries. The use of communal grazing areas in these countries favours the spread of GIN infections across small ruminants and may reduce production performances and herders' income. Faecal samples of 1,235 small ruminants were collected in Burkina Faso, Mali and Senegal in late dry (May), rainy (August) and early dry (November) season of 2022. Individual Faecal Egg Counts (FEC) were performed by a modified McMaster technique. Animals were selected in several villages according to the following parameters: species (sheep, goats), age (young: 6–12 months, adult: >12 months) and sex (male, female). The Kruskal-Wallis test was applied to assess the influence of these parameters on FEC intensity, expressed as eggs per gram of faeces (EPG). The overall prevalence of GIN was 70.8 %, 82.6 % and 66.8 % in Burkina Faso, Mali and Senegal, respectively. In all countries, the rainy season corresponded to the highest infection period. The mean $\pm$ standard deviation of EPG across all countries was 230 $\pm$350, 1,023 $\pm$1,176 and 424 $\pm$352 for late dry, rainy and early dry season. Infection intensity was higher in young than in adult animals, and in male than in female animals in the rainy season, whereas no differences could be observed between these

Contact Address: Linda Cletchio Gabriella Traoré, Nazi Bony University (UNB), Dept. of Animal Prod. Syst. (SNA/SPA), 04, Rue Guisga, 8645 Ouagadougou, Burkina Faso, e-mail: gabriella.traore@yahoo.fr

groups in the late dry season. Similarly, there was no significant difference in the mean EPG between sheep and goats late dry season. The results indicate that better monitoring and control of GIN infections are necessary during the rainy season and especially in young and male sheep and goats. For further study it would also be interesting to learn more about anthelmintic resistance in GIN and non-allopathic control options.

Keywords: Faecal egg counts (FEC), gastrointestinal nematodes, prevalence, small ruminants, West Africa

Surveillance of climate-sensitive zoonotic diseases: Leptospirosis at livestock slaughterhouses in three regions of Uganda

Lordrick Alinaitwe[1,3], Martin Wainaina[2], Kristina Roesel[1], Clovice Kankya[3], Salome Duerr[4], Martin Richter[2], Elizabeth Cook[1], Anne Mayer-Scholl[2]

[1]*International Livestock Research Institute (ILRI), Kenya*

[2]*Federal Institute for Risk Assessment, Dept. of Biological Safety, Germany*

[3]*Makerere University, College of Veterinary Medicine, Animal Resources and Biosecurity, Uganda*

[4]*University of Bern, Veterinary Public Health Institute, Switzerland*

Leptospirosis is an important bacterial zoonosis worldwide and is disproportionately associated with low-income settings and with extreme weather events due to climate change. Transmission to humans often occurs when infected rodents and domestic animals contaminate the environment via urine as the bacteria preferentially colonise kidneys. Surveillance of leptospirosis at slaughterhouses can therefore be useful in providing information on vast areas of a country and screening for diseases that are not considered during animal inspections.

We determined the prevalence of *Leptospira* bacteria in the kidneys of 2,030 livestock kidney samples (820 cattle, 761 pigs, 335 goats, 114 sheep), and 117 small mammals by real-time PCR in a cross-sectional survey of slaughter facilities in three regions in Uganda. We extracted DNA and performed real-time polymerase chain reaction (PCR) tests targeting the *lipL32* gene for pathogenic leptospires. Positive samples with cycle threshold values below 38 were further characterised using single locus sequence typing (SLST) to determine likely genomospecies. PCR products were sequenced by Eurofins Genomics (Ebersberg, Germany) and identification of genomospecies was done using the basic local alignment search tool (BLAST). Multi-locus sequencing typing (MLST) was performed on selected SLST-positive samples to determine sequence types (ST) and likely serogroups. The allelic profiles were analysed using Bionumerics software and the sequence types were determined using the PubMLST database.

An overall prevalence of pathogenic leptospires of 2.58 % (95 % confidence intervals [CI]: 1.89–3.42) was observed, with sheep having the highest prevalence (6.12 % CI: 2.69–12.89), followed by cattle (4.25 %, 95 % CI: 2.91–5.98), goats (2.08 %, 95 % CI=0.91–4.38), and pigs (0.46 %, 95 % CI = 0.12–1.31) in decreasing order. The genomospecies *L. borgpetersenii* (11 in cattle and one in

goat), *L. kirschneri* (five in cattle and four in sheep) and *L. interrogans* (one in a pig) were determined. Preliminary MLST results on one sample reveal *L. kirschneri* ST62 which is related to serogroup Grippotyphosa.

Surveillance of important zoonoses using slaughterhouses as sentinels has the potential to offer essential information on the epidemiology of important zoonotic diseases in Uganda.

Keywords: Climate sensitive diseases, disease surveillance, slaughterhouse

Sustainable feed and forage options for livestock development in Uzbekistan

Rein van der Hoek

The Alliance of Bioversity International and CIAT, West Africa, Senegal

In Uzbekistan, livestock production accounts for 40 % of agricultural output. Since independence, areas planted with forage and feed crops have decreased by 70 %, whereas the cattle population has increased by 150 %, leading to a sharp increase in GHG emissions (mainly methane through enteric fermentation). Inadequate management practices, aggravated by climate change, have led to salinisation and pasture degradation.

Private farms account for over three-fourths of the total area dedicated to feed production. Small Dehkan farms account for only 13 percent of the forage area with almost 95 % of the cattle herd and rely on low-quality communal pastures and (purchased) crop and agro-industrial by-products.

For both farm types the environmental impacts and climate change mitigation potential of improved feed and forages were analysed using an ex-ante assessment tool (CLEANED) for two scenarios: the current situation "Business as Usual" (BAU) and a scenario with feed and forage options including silvopastoral systems with drought resistant and salt-tolerant legume shrubs/trees, high-quality agro-industrial by-products such as cotton seed cake and on-farm forage production (legumes and cereal crops).

Improved feed and forage options reduce environmental and climate impacts, decrease land, water and fertiliser requirements and increase biodiversity and resilience to climate change and weather shocks. GHG emissions fall by 15 %, whereas productivity increases by 20 % and profitability by 25 %.

Within a conducive policy framework, investments should be aimed at knowledge generation, institutional strengthening and overcoming barriers for adoption of feed/forage options and scale sustainable livestock production technologies and practices. Improved farmer access to tools, training (forage production, formulation of rations), technologies, markets, veterinary care and breeding is crucial. Interventions need to be complemented with research on livestock management and productivity increase, and economically feasible options need to be further identified for improving feeding practices.

Keywords: CLEANED tool, environmental impacts, improved feed and forage options, livestock production, Uzbekistan

Development of a fluorescent RBL reporter system for diagnosis of porcine cysticercosis

Md. Shahadat Hossain[1], Phil Toye[2], Lian Thomas[2], Franco H. Falcone[1]

[1]*Justus Liebig University Giessen, Institute of Parasitology, Germany*
[2]*International Livestock Research Institute (ILRI), Kenya*

Porcine cysticercosis (PCC) is a World Organisation for Animal Health listed notifiable disease in pig, caused by the larval stage of Taenia solium. Pigs get infected by ingesting human stool or water/vegetation contaminated with *Taenia solium* eggs. The disease is endemic in Latin America, sub-Saharan Africa, as well as South and South East Asia. PCC hampers food security and affects livelihoods of pig farmers resulting in reduced pork value and economic loss, especially in developing countries. Available serological diagnostic tests based on IgG detection are characterised by low specificity. This study aims to assess suitability of detecting parasite-specific Immunoglobulin E (IgE) using IgE based reporter cell lines. Our objectives are to create a reporter cell line that is able to bind pig IgE and to identify, clone, and recombinantly express candidate *T. solium* allergens, which will be assessed for their suitability as 'diagnostic allergens' for diagnosis of PCC. We cloned a synthetic pig high affinity IgE receptor alpha chain (Ss-FCER1A) into a plasmid vector (pcDNA5). After ligation and bacterial transformation, we transfected our target transformant (Ss-FCER1 ^{A}/$_{pcDNA}$5) into Rat basophilic leukemia (RBL) cells stably transfected with neuropeptide Y monomeric red fluorescent protein (NPY-mRFP) and developed a chimeric pig/rat 'porcinised' reporter system (RBL NPY-mRFP Ss-FCER1A). The developed cell lines were then continuously sub cultured for selection of stable transfectants. Five diagnostic *T. solium* oncospheral allergens (Q9NI46, Q2XNL7, K0A0S9, E5LBB8, W8P1J2) were identified through employing several immunological and bioinformatic techniques aiming to identify IgE-immunoreactive antigens. These coding sequences for the selected allergens were then cloned into pTT expression vectors and subsequently transformed into bacteria cells for plasmid amplification. We are currently attempting recombinant expression of those cloned products in HEK293–6E cells grown in suspension. Once the expressed IgE immunoreactive antigens have been purified, we will assess their suitability as diagnostic antigens using our reporter system. This study is expected to enable development of a novel IgE- based serological diagnosis of PCC, which will be helpful for reliable identification of *T. solium* infection in endemic countries.

Keywords: Allergens, diagnosis, IgE, NPY-mRFP, porcine cysticercosis, RBL, reporter system, *Taenia solium*

Contact Address: Md. Shahadat Hossain, Justus Liebig University Giessen, Institute of Parasitology, Schubertstraße 81, 35392 Gießen, Germany, e-mail: shahadat.para@bau.edu.bd

Phenotypic diversity and local adaptation of Sahelian goat populations in Niger

Regina Roessler[1], Andreas Buerkert[2]

[1]University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany
[2]University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

Rapid population growth, climate change, and desertification continue to contribute to increasing pressure on populations of small ruminants in the West African Sahel. The most vulnerable breeds may be seriously threatened, calling for stepping up conservation efforts for well-adapted populations. Goats are essential for ensuring food security and resilient transformation of food systems in the region. As a first step in the planning of conservation efforts for goats in Niger, we phenotypically characterised Sahelian goat populations in oasis systems in northern Niger (O) and from contrasting systems in the northern and southern Niger (OT). We hypothesised that communities in oasis systems intentionally selected goats for high capability to survive under extreme environmental conditions and that all goats constitute distinct populations within the Sahelian goat breed. To test this hypothesis a total of 197 goats were characterised for body coat pattern and colour, hair type, ear orientation and absence/ presence of horns, wattles, and beard. Phenotypic frequencies were computed by direct count and phenotypes were classified into typical (occurrence $\geq 50\%$ of all goats), intermediate (occurrence 11–49 %), and unusual (occurrence $\leq 10\%$). The allele frequency of the recessive allele was calculated for the horned, wattled, and bearded locus using the Hardy-Weinberg equilibrium. Observed allele frequencies were tested against their expected Mendelian allele frequencies using X^2 tests. The data show that typical phenotypes of goats in Niger are horns (98.5 %), short body hair (96.6 %), long pendulous ears (60.0 %), and absence of both beard (60.4 %) and wattles (58.7 %). Unbearded goats tended to be more common in OT than in O. Similarly, spotted body coat was less frequent in O goats, while fawn and black goats and goats with long hair were more common in O. The dominant alleles for horns, wattles and beard were found to segregate at lower frequencies than expected, except for beard in female goats in OT. Research on the genetic differentiation between highly fragmented goat populations within the country is ongoing to confirm that goats in the oasis systems in northern Niger represent distinct populations within the local Sahelian goat breed.

Keywords: Goat diversity, Niger, oasis agriculture, selection pressure

Towards more efficient and sustainable production in Egyptian buffalo: The clue lies in the genome

Hamdy Abdel-Shafy[1], Mohamed A.A. Awad[1], Hussein El-Regalaty[2], Salah El-Dien El-Assal[3], Samy Abou-Bakr[1]

[1]*Cairo University, Fac. of Agriculture, Dept. of Animal Production, Egypt*

[2]*Agricultural Research Center, Animal Production Research Institute, Dept. of Buffalo Research, Egypt*

[3]*Cairo University, Fac. of Agriculture, Dept. of Genetics, Egypt*

The biodiversity and food security nexus is critical to ensure sustainable food production. Local livestock breeds, such as the Egyptian buffalo, play a vital role in providing animal protein to the local community. However, the potential of this species is often underestimated and underutilised due to the lack of national recording systems and insufficient pedigree information, which pose significant challenges for traditional breeding schemes. In addition, uncontrolled insemination with imported semen beside the current economic crisis, which led to a significant reduction in the number of Egyptian buffalo by 60 % in the last five years, put the genetic diversity and potential of this breed at risk. To address these challenges, we integrated genomic information into breeding evaluations for the first time in Egyptian buffalo. By genotyping hundreds of animals, we evaluated their production potential and established a basic population for more accurate prediction of economically important traits, e.g. milk production and composition. Our results demonstrated more reliable estimation of genetic parameters from a population with small size using a single-step genomic evaluation. The identified genomic regions harbor promising candidate genes with biological roles associated with milk production traits, e.g. POU2F1 on chromosome 6; TPD52, ZBTB10, RALYL and SNX16 on chromosome 15, ADGRD1 on chromosome 17, ESRRG on chromosome 5 and GRIP1 on chromosome 4. These findings provide useful information for exploring the genetic mechanisms underlying milk production traits and have significant implications for food security and small-scale farmers who own over 85 % of Egyptian buffalo. Integrating genomic information for genetic evaluation can play a critical role in achieving sustainable genetic improvement and preservation of the genetic diversity of this important breed. In conclusion, our work demonstrates the potential of integrating genomic information into selection decisions for Egyptian buffalo, even with a small sample size, to achieve more efficient and sustainable production while preserving genetic diversity.

Keywords: Egyptian buffalo, genomic evaluation, SNPs

Contact Address: Hamdy Abdel-Shafy, Cairo University, Fac. of Agriculture, Dept. of Animal Production, El-Gamaa Street, 12613 Giza, Egypt, e-mail: hamdyabdelshafy@agr.cu.edu.eg

Benefits and financing options supporting the adoption of an East Coast fever vaccine in Tanzania

Simon Minz[1], Nils Teufel[2], Eva Schlecht[3]

[1]*University of Kassel, Animal Husbandary in the Tropics and Subtropics, Germany*
[2]*International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kenya*
[3]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

The "Infection and Treatment Method" (ITM) is a strategy to mitigate severe cattle losses in Eastern Africa caused by East Coast fever, a tick-borne disease. ITM involves intentionally infecting cattle with a low dose of the disease-causing pathogen, followed by treatment with antibiotics. This approach has been shown to provide several benefits, including reduced disease incidence, improved animal health, and increased productivity.

However, the full potential of ITM is not always realised due to challenges such as vaccination cost management and implementation complexity. In this poster presentation, we will discuss the benefits of ITM from the farmers' perspectives through analysing a data set recorded in Tanzania, including reduced disease incidence, improved animal health, and increased productivity. We will also explore what farmers have changed after implementing ITM, such as improvements in animal management practices and increased awareness of disease prevention strategies.

One of the major challenges for the adoption of ITM is the cost associated with vaccination. We will present the financing strategies that farmers use to pay for ITM vaccination, including government subsidies, community financing, and other financing mechanisms. Additionally, we will examine the credit option some animal health care providers offer to support farmers in managing the costs associated with ITM implementation.

A better understanding of the benefits and financing strategies of ITM for cattle health in Eastern Africa from the farmers' perspective will allow development stakeholders to more effectively improve the technical, business and institutional aspects of last-mile delivery systems of the vaccine. Only if the current constraints in vaccine delivery be successfully addressed can the vaccine achieve its potential to support livestock keepers in achieving significant livelihood improvements.

Keywords: East Coast fever, financing strategies by farmers

Contact Address: Nils Teufel, International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kabete, Old Naivasha Road, PO Box 30709, 00100 Nairobi, Kenya, e-mail: n.teufel@cgiar.org

Ultrasonic measurements of fetal parameters for estimation of gestational period in Nubian goats supplemented with *Moringa oleifera* leaves

Faisal Ahmed[1], Nahla Elhassan[2], Magdalena Mohammed[3]

[1]University of Khartoum, Dept. of Reproduction and Obstetrics, Sudan
[2]University of Khartoum, Dept. of Animal Prodcution and Animal Nutrition, Sudan
[3]Gamers University, Goats Research Center, Sudan

The present study aimed to evaluate the influence of *Moringa oleifera* (MO) leaves supplement to the pregnant goat feed on fetal growth in Nubian goats in Butana area using the application of real-time ultrasnography and to determine the relationship between the gestational period (GP) with the measurements of crown rump length (CRL), biparietal diameter (BPD) and femur length (FL). Twenty (20) multiparous apparently healthy Nubian does with fair body condition score (BCS) and 1.5–2 years old were used in this study. The animals were allocated randomly according to the level of MO leaves supplemented in the roughages. Measurements were taken three times within the pregnancy period for measuring the CRL, BPD and FL. Crown rump length measurement at day 45 of pregnancy, showed significant difference ($p < 0.05$) between groups. The highest mean measurement for CRL (4.63 ± 0.69 cm) was achieved in group D, while the lowest mean value (3.60 ± 0.53 cm) was recorded in group B. Mean value for FL measurement (2.24 ± 0.42 cm) and BPD measurement (2.40 ± 0.70 cm) at day 80 of pregnancy, showed no significant difference between groups ($p > 0.05$). The results demonstrated that CRL, BPD and FL were significantly correlated with GP ($p < 0.05$). The CRL was positively correlated with GP (R =0.501) followed by the BPD (R =0.614) and the FL was strongly positively correlated with GP (R =0.957). Supplementation of MO leaves for pregnant Nubian does indicated that, CRL, FL and BPD measurements were correlated to fetal age. Mean values of crown crump length (CRL) obtained at day 45 of pregnancy, were significantly different ($p < 0.05$) between groups. The longest measurements were found in group D (4.63 ± 0.69 cm) while the least mean value was recorded in group B (3.60 ± 0.53 cm). The best time to obtain the measurements for the femur length was at the end of the 2nd trimester of pregnancy. The current study concluded that, supplementation of *Moringa oleifera* in goat feed, does not influence significantly the measurements of femur length and biparietal diameter of the fetus, while the measurements of crown rump length is influenced.

Keywords: Fetal measurements, gestational age, Nubian goats

Contact Address: Nahla Elhassan, University of Khartoum, Dept. of Animal Production and Animal Nutrition, Athora Alnosalhara 17, 1111 Omdurman, Sudan, e-mail: nahlavetxx@hotmail.com

Intake and digestibility of four rations with different fibre levels in alpacas (*Vicugna pacos*)

Carlos Alfredo Gómez Bravo[1], Ana Belén Obrégon-Cruz[1], Cesar Osorio[2], Robert Van Saun[3]

[1]*Universidad Nacional Agraria La Molina, Peru*
[2]*Instituto Nacional de Innovación Agraria, Peru*
[3]*Pennsylvania State University, State College, United States*

In Peru there are about 4.500.000 camelids, which are raised in an extensive system, where the diet is based on the intake of highly fibrous natural grasses. The aim of this study was to evaluate the effect of different dietary fibre levels on intake and apparent nutrient digestibility of nutrients in alpacas, and to estimate the digestibility of organic matter (OMD) from the content of crude protein (CP) in faeces. The study was carried out with twelve alpacas (36.7 $\pm$ 6.4 kg body weight - BW), which were offered 4 treatments with different neutral detergent fiber content (NDF. T1: 40.3 %; T2: 62.1 %; T3: 67.8 %; T4: 71.6 %) under a switch back design. Dry matter intake (DMI) was higher for T1 (612 g d^{-1}) while T4 consumed less (470 g d^{-1}; $P \leq 0.05$), when correcting DMI for BW and metabolic weight (MW) was equal between treatments ($P \geq 0.05$). The NDF intake was similar between treatments when related to BW or MW (on average 1 % BW and 23.2 g kg^{-1} BW$^{0.75}$; $P \geq 0.05$). Water intake (L day^{-1}) was higher in T1 compared to the other treatments, with values ranging from 1.8 L day^{-1} (T1) to 1.4 L day^{-1} (T4), respectively ($P \leq 0.05$). Digestibility of dry matter, organic matter and crude protein was higher in T1 than in the other treatments, with average values ranging from 65 % for T1 to 48 % for T4 ($P \leq 0.05$). The NDF digestibility was similar among treatments ($P \geq 0.05$). The regression equation generated to predict OM digestibility (y) was as follows: y = 0.07635- (-0.33866*exp (-(-0.51457) × faecal CP (g kg^{-1} OM)/100)). Further studies will indicate whether faecal nitrogen can be used to estimate digestibility and hence diet quality in South American camelids.

Keywords: Digestibility, faecal nitrogen, nutrient intake, South American camelids

Practices and drivers for antibiotic use in Kenyan small-holder dairy farms

Lydiah Kisoo[1], Dishon Muloi[1], Lillian Wambua[2], Eric Fèvre[3], Arshnee Moodley[4,1]

[1]*International Livestock Research Institute (ILRI), Kenya*

[2]*World Organization for Animal Health (WOAH), Sub-Regional Representation for Eastern Africa, Kenya*

[3]*University of Liverpool, Inst. of Infection, Veterin. and Ecological Sci., United Kingdom*

[4]*University of Copenhagen, Denmark*

Understanding antibiotic use is critical for developing effective interventions, particularly in light of the global actions to reduce antibiotics in food-producing animals. In low and middle-income countries (LMICs), farmers mostly self-diagnose and administer antibiotics without proper guidance from a veterinarian potentially resulting to misuse or overuse. Irrational antibiotic use is a major driver of antimicrobial resistance (AMR) globally, transferrable to humans through the food chain. AMR is one of the biggest threats to human health, and it has been estimated that by 2050, up to 10 million people could die annually due to AMR infections if appropriate measures are not taken to address the issue.

Using a standardised questionnaire, AMUSE version 2, this study investigated the patterns and drivers of antibiotic use in 165 smallholder dairy farms in Machakos, Makueni and Narok Counties in Kenya. We used a causal diagram framework to inform logistic regression models to explore the drivers of antibiotic use in the selected farms.

Antibiotic use was reported in 92.7 % of farms and nearly all of them administered antibiotics primarily for prophylactic purposes. Oxytetracycline, penicillin, and streptomycin were the most used antibiotics to treat mastitis and diarrhea, the most reported bacterial infections. Regression analysis indicated a positive association between the frequency of antibiotic use at the farm level and both disease incidence (measured as the number of new cases in the previous year) and herd size. Conversely, farms that provided cattle with appropriate housing were less likely to use antibiotics, and there was no difference in antibiotic use between those who consulted with veterinarians or sourced antibiotics directly from animal health providers.

Our study highlights the complexities around understanding the interplay between practices and drivers of antibiotic use and underscores the necessity to enhance education regarding the appropriate usage of antibiotics among dairy farmers, encourage the adoption of proper cattle herd management practices which may reduce the disease burden, and reinforce veterinary services to promote the prudent use of antimicrobials.

Keywords: Antibiotic use, dairy farms, antimicrobial resistance

Contact Address: Lydiah Kisoo, International Livestock Research Institute (ILRI), Animal and Human Health, Old Naivasha Road, P. O. Box 30709-00100 Nairobi, Kenya, e-mail: L.Kisoo@cgiar.org

Liver histopathology and growth performance of turkey poults fed with aflatoxin contaminated diets supplemented with nevatox binder

Adekoyejo Oyegunwa, Hassan Kassim, Oluwole Banjo

Tai Solarin University of Education, Agricultural Science, Nigeria

Aflatoxin has become a nightmare in poultry industry affecting the birds as a result of various diseases caused by ingestion of the toxin. Clay minerals has however shown some potency in neutralizing the effect of the disease on broilers and other class of poultry, while such information in turkey management is scanty. Therefore this study was conducted to investigate the efficacy of Nevatox, a clay mineral in ameliorating aflatoxicosis in turkey poults

A total of 80, 21-d-old turkey poults were randomly allotted to five dietary treatments with four replicates of four poults per replicate in a completely randomised design. Treatment 1 is positive control diet with no aflatoxin and no nevatox, treatment 2 is the negative control with 0.2 ^{mg}/kg of aflatoxin, treatment 3 is the negative control with 2.0 ^{g}/kg Nevatox, treatment 4 is the negative control with 4.0 ^{g}/kg Nevatox, treatment 5 is the negative control with 6.0 ^{g}/kg Nevatox. The feeding trial lasted for 21 days. At the end of the feeding trial, performance data were collected for feed intake, body weight gain and mortality while 2 birds per replicate were killed and their liver harvested for histopathology examination.

Significant reductions were observed in that feed intake (1087.50g, 632.10g, 570.50g, 525.00g, & 650.00g)and body weight gain (365.00g, 129.00g, 140.20g, 151.00g & 70.25g) of the poults at the end of the feeding trial while mortality figures (0 %, 36 %, 24 %, 30 % & 28 %) were significantly higher in all treatments that received aflatoxin including treatments with Nevatox. In addition, Induced pathological lesions were observed in the liver of birds fed treatments 2 to 5. Supplementation of the diet with Nevatox at 2, 4 and 6 ^{g}/kg did not improve the performance of the birds.

It can be concluded from the results that dietary supplement of Nevatox at the levels prescribed had no protective effect against aflatoxicosis caused by aflatoxin B1 in turkey poults

Keywords: Aflatoxin B1, detoxification, histopathology, nevatox, turkey poults

Extent of livestock and cropping enterprises in selected counties in Kenya: An assessment

Solomon Mwendia[1], Ben Lukuyu[2], Kevin Maina[3], Ruth Odhiambo[1], Fredrick Muthomi[1], Kenneth Waluse[1]

[1]*The Alliance of Bioversity International and CIAT, Kenya*
[2]*International Livestock Research Institute (ILRI), Feeds and Forages Program, Uganda*
[3]*International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kenya*

Mixed farming systems in East Africa continue to interplay. While livestock and crops play critical roles in practicing households including human nutrition, incomes, and as a form of savings/insurance; synergic and complementarity e.g use of livestock manure to fertilise croplands, and crop residues for livestock feed, prevail, an important driver contributing to the practice. Within the wider content of deriving livelihoods under such systems, it becomes important to understand dynamics of the enterprises especially competing for land allocation. How the communities perceive and assign land to the mixed farming activities including gender decision making, especially from incomes realised, is important in designing interventions. In this context, we selected two administrative counties in Kenya (Kisii, Meru) where mixed farming is important and administered Gendered- Feeds Assessment Tool (G-FEAST). The tool involves engaging the communities, and returns perceptions on land sizes, main crops grown and household decisions on incomes. Small land (ha) is taken as <0.25 in both counties, while large land is considered as >2 (Meru) and >3 (Kisii). Improved dairy cattle take the largest Tropical Livestock Unit (TLU) ranging between 2–5, while the leading crop (ha) is *Zea mays* with land allocation of 0.16 in Kisii, and tea in Meru 0.27 ha. A mix of gender decisions on household incomes was observed where men are more involved in cash crop and dairy income in both counties, and women on off-farm business and poultry eggs in Meru and, poultry meat and eggs in Kisii. While targeting improvement options in the studied farming setups, would be important to consider the context presented here, including the gender that may influence uptake of the technologies and advisories under consideration.

Keywords: Gender, livestock, mixed farming

Contact Address: Solomon Mwendia, The Alliance of Bioversity International and CIAT, Nairobi, Kenya, e-mail: s.mwendia@cgiar.org

Benefits of Leucaena diversifolia in grazing steers diet: Performance, methane and fatty acids

Isabel C. Molina-Botero[1], Daniel Mauricio Villegas[1], Alejandro Montoya[1], Johanna Mazabel[1], Mike Bastidas[1], Herman Gaviria[2], Juan David Peláez[2], Julián Chará[3], Enrique Murgueitio[3], Jacobo Arango[1]

[1] International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia
[2] Asobrangus Comercial ANGUSAZUL, Trop. Forages Program, Colombia
[3] Center for Research on Sustainable Agricultural Production Systems - CIPAV, Colombia

Leucaena diversifolia (Ld) is a legume species that has received little attention in terms of its nutritive value, methane (CH_4) emissions, and impact on meat quality. To address this gap, a study was conducted to compare the performance, CH_4 emissions, and fatty acid content of steers grazing on a monoculture of tropical grass *Urochloa* hybrid cv. Cayman versus a combination of Cayman and Ld. Over a period of 15 months, 14 Angus crossbred steers weighing an average of 374 ± 7.5 kg were used in the study, with half of them grazing only Cayman grass and the other half grazing on a combination of Cayman and Ld at a ratio of 74:26. Live weight gain was recorded and CH_4 emissions were measured after the animal productivity test. Meat quality and fatty acid profiles were measured after the steers were slaughtered.

The results showed that steers grazing on a combination of Cayman and Ld consumed more dry matter, crude protein, and energy per day than those grazing on grass alone, and this difference was still evident when digestibility was considered ($P \leq 0.05$). Moreover, animals grazing on a combination of Cayman and Ld weighed an average of 63 kg more at the end of the experiment compared to those grazing only Cayman (466 vs. 403 kg; $P \leq 0.05$). Interestingly, animals that consumed only Cayman grass emitted more CH_4 than those that included Ld in their diet (168 vs. 144 g d^{-1}; $P \geq 0.05$). The total polyunsaturated, monounsaturated, and saturated fatty acid concentrations in the meat did not differ between the two groups ($P \geq 0.05$).

In conclusion, incorporating Ld in the diet of grazing steers can increase nutrient intake (protein and energy) and animal productivity without affecting daily net CH_4 emissions or fatty acid concentrations in the meat. This study sheds light on the potential benefits of legume inclusion in animal diets and highlights the need for further research in this area.

Keywords: Animal productivity, grasses, silvopastoral systems, unsaturated fatty acids

Influence of the quarter-individual milking system "MultiLactor" on the milk yield and quality in dairy cows: Results of a field study

Shehadeh Kaskous

Siliconform, Department of Research and Development, Germany

The mechanical forces during machine milking lead to changes in the teat tissue. This effect is related to the degree of adaptation of the milking machines to the physiological requirements of the dairy cows. If the milking machine settings and liners are not suitable for all dairy cows on the farm, the teat condition will deteriorate and some animals may suffer from mastitis. In addition, the purpose of milking machines is to harvest milk at optimal speed while maintaining animal comfort and teat defence mechanisms against invading mastitis pathogens. Therefore, the milking machine is a crucial factor in optimising milk yield and quality. The aim of this study was to examine the influence of a quarter-individual milking system "MultiLactor" (ML) on milk yield and quality. 170 Holstein-Friesian dairy cows were used on a farm in Switzerland. The cows were milked three times a day with an ML milking system. The working vacuum level was 36 kPa and sequential pulsation (25 % each quarter) was adopted. The pulsation rate was 60 cycles per minute and the pulsation ratio was 60/40 during the milking time. Milk yield recording and milk sampling were performed monthly for one year from each cow. The major milk parameters were then analysed by the Swiss milk record Association. For statistical evaluation, the mixed procedure of SAS was used. Significant differences ($p < 0.05$) were localised using the LSD test. Mean milk yield was $35.84 \pm 0.28\,\mathrm{kg\,cow^{-1}\,day^{-1}}$. This corresponds to an annual milk yield of $12000\,\mathrm{kg\,cow^{-1}}$. Mean milk composition values were $4.36 \pm 0.02\,\%$, $3.28 \pm 0.01\,\%$, $4.75 \pm 0.01\,\%$, $20.65 \pm 0.20\,\mathrm{mg\,dl^{-1}}$ and $99.63 \pm 6.48 \times 10^3\,\mathrm{cells\,ml^{-1}}$ for fat, protein, lactose, urea, and somatic cell count (SCC) respectively. It was also shown that the cows remained healthy on the farm during the study period. In conclusion, an ideal milking machine adapts to the morphological, anatomical, and physiological characteristics of the udder and teats of dairy cows and it should achieve a physiological ideal milking process meeting high animal welfare standards for increased milk production with high quality standard.

Keywords: Cow, fat, lactose, milk, MultiLactor, protein, SCC, urea

The status of knowledge, attitudes, and practice in the cultivation and usage of improved forages in Kenya and Uganda

Kenneth W. Sibiko[1], Margaret Lukuyu[1], An Notenbaert[1], Stefan Burkart[2]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Kenya*

[2]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia*

There is a scarcity of published literature about farmers' level of knowledge, attitudes, and practices regarding improved forage varieties in East Africa, particularly among the populations where development projects have been and continue to be implemented. This study was carried out to address this knowledge gap and strengthen future scaling activities. We rely on cross-sectional data with a sample of 353 respondents equally drawn from treatment and control areas across 3 districts in Kenya and Uganda respectively. Pairwise correlations, t-tests, and left-censored Tobit regression were utilized for the analysis. Results indicate that treatment areas have significantly higher levels of knowledge and have more positive attitudes toward improved forage cultivation and use compared to the control areas. However, Kenyan farmers seemed generally more knowledgeable (at 3.16 on a scale of 1-5) and portrayed positive attitudes than their Ugandan counterparts (2.18) within the intervention areas. Regarding the actual forage adoption, it is observed that the majority (91 %) of the respondents in Kenya cultivated at least one forage crop on their farms, which was more than double the percentage (38 %) who cultivated forages in Uganda. The most important factors influencing the area planted with forages were participation in forage training events, the size of land and number of cattle owned, as well as the education and experience levels of farmers. In Kenya, we also observed a significant positive correlation between different extension approaches (radio programs, attending field days, TV programs, farmer field schools, farmer-to-farmer exchange, formal workshops) and the respondents' knowledge levels. The findings show that a great milestone has been achieved in creating awareness among Kenyan farmers. Similar intensified campaigns will be required in Uganda and other East African countries to scale out the adoption of high-quality forages in these countries.

Keywords: Adoption, Africa, attitudes, forages, knowledge, practice, scaling

Contact Address: Kenneth W. Sibiko, The Alliance of Bioversity International and CIAT, Trop. Forages Program, ICIPE Duduvile Campus P.O. Box 823-00621, Nairobi, Kenya, e-mail: K.Waluse@cgiar.org

Tracing the origin of external feed inputs to assess the circularity of livestock farming systems in Kenya

Dagmar Braamhaar, Simon Oosting

Wageningen University and Research, Animal Sciences, The Netherlands

The consumption of animal-source food (ASF) is expected to increase in developing countries. However, ASF production negatively affects the environment (e.g., via greenhouse gas emissions, land use change, loss of biodiversity), and therefore should be produced in a more sustainable manner. A circular food system is seen as a promising way to use resources effectively and to reduce the impact on the environment. In circular food systems, losses of resources should be prevented and otherwise recovered for reuse. A backbone of circular food systems is avoiding feed-food competition by letting livestock only utilise low-opportunity cost feed (LCF; i.e. by-products, waste-products, grass from land unsuited for food crop production). Livestock can turn these LCF products into nutritious food, manure, and other ecosystem services. However, policymakers often focus on increasing livestock production through intensification practices that increase the need for high quality inputs such as maize and concentrate as detriment of LCF. Hence, intensification will increase feed-food competition and sourcing of products from neighbouring countries, and consequently interrupt nutrient cycling and circularity. We characterised the diet composition and identified input suppliers of small- and large-scale pig, poultry, and dairy farms in Njoro Ward located in Nakuru County in Kenya via in-dept interviews with livestock farmers. Subsequently, input suppliers (e.g. agrovets, wholesalers, feed processing factories,) were interviewed to trace the origin of external inputs. As a result, we assessed circularity of livestock farming systems at ward level and identified opportunities and challenges to implement circular systems at the system production level. Results showed a high dependency on imported ingredients to produce compound feed (e.g., dairy meal, pig finisher meal, layer mash). Protein rich ingredients (i.e. soybean meal, sunflower seed cake, rapeseed cake) were often supplied from other East-African countries, while feed additives (minerals, DCP, toxin binder) were often supplied from global market.

Keywords: Circularity, feed-food competition, food system, intensification, livestock

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Contact Address: Dagmar Braamhaar, Wageningen University and Research, Animal Sciences, De Elst 1, 6708 WD Wageningen, The Netherlands, e-mail: dagmar.braamhaar@wur.nl

Evaluation of nonstructural carbohydrate traits of Napier grass (*Cenchrus purpureus*) genotypes grown under field drought stress condition

Aster Gebisa[1], Ermias Habte[2], Abel Gari[2], Helen Nigussie[1], Chris Jones[2]

[1]*Addis Ababa University, Dept. of Applied Genetics, Ethiopia*

[2]*International Livestock Research Institute (ILRI), Feed and Forage Development Program, Ethiopia*

Napier grass (*Cenchrus purpureus* Shumach) is a C4 perennial forage grass majorly used as livestock feed in tropical and subtropical environments. However, the productivity of Napier grass is affected by drought stress that in turn inhibits feed quality traits accumulation such as the non-structural carbohydrate (NSC) concentration accumulation and transportation. NSC is one of the cell components that are associated with tolerance to environmental stress such as drought stress as it can minimise the impacts of stress via changes in carbon balance. A study was conducted to evaluate the NSC level of 76 Napier grass genotypes under different soil moisture stress levels (moderate and severe soil moisture stress conditions) and to identify the genetic variants associated with NSC traits. The genotypes of Napier grass were grown either in moderate or severe soil moisture levels using a partial replication design in four blocks. The oven-dried leaf samples that are harvested after eight weeks of growth were ground to quantify water-soluble carbohydrates (WSC) and starch using a spectrophotometer. High variation for NSC and WSC values was observed among genotypes and stress levels. Under moderate soil moisture stress, genotypes that showed high NSC levels were 16797, 16810, and 16802 while, under severe stress genotypes that produce high NSC levels were 16789, 16800, and 1026. Comparing the two moisture stress levels, the highest values for NSC was observed under moderate condition than under severe condition. Furthermore, the genome-wide association study identified two significantly associated SNPs (SGWHAORA00000009_160387802 and SGWHAORA00000009_101547011) in both moisture stress levels. Generally, the concentration of NSC traits was shown to be dependent on the level of soil moisture conditions and genotype.

Keywords: Drought stress, feed quality traits, Napier grass, non-structural carbohydrate, starch, water soluble carbohydrate

Nutritional values of indigenous browse and herbaceous legume species for ruminants in Ethiopia: a meta-analysis

Sisay Belete[1], Adugna Tolera[1], Uta Dickhöfer[2]

[1]*Hawassa University, School of Animal and Range Sciences, Ethiopia*
[2]*Christian-Albrechts-Universität zu Kiel, Inst. of Animal Nutrition and Physiology, Germany*

Browse trees/shrubs and herbaceous forage legumes play a crucial role in providing nutrients for livestock, particularly ruminants. Due to their high protein content and better digestibility compared to common tropical grasses, they have the potential to be used as protein-rich supplements for ruminants. Thus, proper utilisation of these underutilised fodder sources in Ethiopia requires establishment of comprehensive data on their nutritional composition and performance response of ruminants to the diets containing these feed resources. This quantitative review summarised nutritional value and the effects of including foliage from browse species and herbaceous forage legumes in the diets of ruminants. Herzing's Publish or Perish free software was used to identify 134 papers published in Ethiopia (62 on the *in vitro* nutritional value and 72 on *in vivo* studies) from the web databases of Google Scholars, Scopus, and PubMed. The results demonstrate that although the nutritional values are largely variable, foliage of browse species and herbaceous forage legumes studied can be classified as nutrient-rich diets for ruminants. Browse species and herbaceous forage legumes had crude protein content of 17.3 % (5.2–32.4 %) and 20.2 % (9.1–30.1 %), and *in vitro* organic matter digestibility of 59.3 % (33.2–89.3 %) and 54.7 % (39.7–69.3 %), respectively. Because of these nutritional advantages and moderate fiber (NDF, ADF, and ADL) concentration, supplementation of both fodder sources to low quality basal diets increased dry matter intake and average daily weight gain of the animals. The presence of large variation in their nutritional composition may provide an opportunity to screen species and varieties of high nutritional quality traits. Moreover, determination of optimum inclusion level is also essential for best performance.

Keywords: Browse species, forage legumes, ruminants

Contact Address: Sisay Belete, Hawassa University, School of Animal and Range Sciences, Tabor 05, Hawassa, Ethiopia, e-mail: cisbelete@gmail.com

In vitro gas fermentation assessment of shed leaves of some predominant plants as ruminants' forage

Victor Akinwande[1], Adejoke Adeneye Mako[1], Oluwanike
Abiola-Olagunju[2], Folake Sodique[1]

[1]*Tai Solarin University of Education, Agricultural Science, Nigeria*
[2]*Lead City University, Microbiology, Nigeria*

Sometimes, some deciduous plants shed their leaves, which litter the environment and perhaps can be utilised as forage resources. Chemical composition and *in vitro* gas production parameters of shed leaves from different browse plants (*Tamarindus indica*, *Terminalia catappa*, *Bambusa vulgaris*, *Anacardium occidentale* and *Cola nitida*) were investigated. The shed leaves of each plant were picked, cleaned and milled. Chemical composition and *in vitro* gas production analyses were carried out. Results revealed that significant variations ($p < 0.05$) in all the parameters considered under chemical composition. *Bambusa vulgaris* leaf had the highest (93.10 %) dry matter content, while *Terminalia catappa* leaf recorded the lowest (91.82 %). Same trend was observed for crude protein, with *Bambusa vulgaris* leaf recording the highest (10.90 %) value, while lowest (4.89 %) value was obtained in *Terminalia catappa* leaf. Neutral detergent fibre ranged significantly ($p < 0.05$) from 52.92 to 61.53 % in *Tamarindus indica* leaf and *Terminalia catappa* leaf respectively. Similar pattern was observed for acid detergent fibre (33.13 – 48.95 %) and acid detergent lignin (16.48 – 24.12 %). Among the shed leaves, the highest (10.67 ml/200 mg DM) gas production ($p < 0.05$) was obtained in *Bambusa vulgaris* leaf, while the lowest (6.67 ml/200 mg DM) was recorded for *Terminalia catappa* leaf. *Bambusa vulgaris* leaf recorded highest values for ME (4.34 MJkg^{-1} DM), OMD (30.30 %) and SCFA (0.19 mmol). The methane volume produced ranged from 2.5 to 4.5 ml/200 mg DM in *Terminalia catappa* leaf and *Tamarindus indica* leaf respectively. It can be concluded that these shed leaves have potential in ruminant nutrition and can be used by ruminant farmers to serve as off season forage in the tropics

Keywords: Chemical composition, *in vitro* gas production, ruminants, shed leaves

Chemical composition of willow trees for silage making based on harvest frequency

Rawad Swidan, Sami Awabdeh

National Agricultural Research Center, Livestock Research Directorate, Jordan

A study was conducted to evaluate the chemical composition and biomass production of willow tree for silage making for small ruminant based on harvest frequent. A total of 9 plots (42 trees per plot) were randomly assigned into 3 harvest frequency (3 plots per treatment) per production year. A total of 378 willow trees were all harvested on November and allowed to regrowth for the following year. The regrowth was observed throughout the production year. Plots were harvested on June, September and November for the first treatment (H3); plots in the second treatment (H2) were harvested on July and November, while the third treatment (H1) were harvested once on November. Samples were collected on a monthly basis from both leaves and stem to evaluated the chemical composition of willow trees throughout the production year. Plots were harvested and weighted for each treatment, total mass productions were calculated from the accumulative weight for treatment H3 and H2, while the total mass production for H1 were weighted at the end of the experiment. Average production per tree were also calculated for each treatment. willow leaves and stems were analysed for moisture contents, CP, NDF, ADF, Fiber, either extract and ash. Only moisture and CP contents were significantly different among the treatments. The study shows that moisture content in H3 (62.8 %) and H2 (62.6 %) group were significantly higher than H1 (50.7 %). In addition, H3 and H2 group were significantly higher protein contents (DM basis) compared to H1 (13.2 and 12.7 vs. 9.5 % CP, respectively). The total biomass productions were 173.1, 153.4 and 192.1 kg, with an average forage production of 1.47, 1.58 and 1.60 kg per tree for H3, H2 and H1, respectively. In conclusion, for silage making, harvest willow trees twice or more in a production year produce higher biomass, with higher protein and moisture contents, which is ideal for silage making compare to harvest willow trees once in a production year.

Keywords: Biomass production, chemical composition, harvest frequent, silage making

Contact Address: Rawad Swidan, National Agricultural Research Center, Livestock Research Directorate, Jarash Highway, 19381 Ain Basha, Jordan, e-mail: rawados@gmail.com

Black soldier flies (BSF) as alternative livestock feed in Kenya: Gendered perspectives on business models

Holger Kirscht[1], Collins Bulinda[2]

[1]*International Centre of Insect Physiology and Ecology (icipe), Social Science and Impact Assessment Unit, Kenya*

[2]*Egerton University, Dept. of Agricultural and Agribusiness Management, Kenya*

Poultry and pig enterprises are among the fastest-growing agribusinesses in Sub-Saharan Africa. The conventional animal protein sources for pig and poultry production are fish meal and soybeans. In Kenya, these resources are expensive and limited. There is an overdependence on imports especially for soy protein and the use of small fish used to produce fishmeal already led to overexploitation of Kenyan lakes. The use of insects, especially of black soldier flies (BSF), as a replacement protein source for feed is gaining momentum and BSF production is an emerging business. In this poster we analyse the preference for certain business models used by small and medium scale male and female BSF producers in Kiambu County in Kenya. By using semi-structured questionnaires for data collection we were able to identify three main business models: cyclic, market-driven and out-grower models. The cyclic business model is a circular business model which excludes the market. Available organic waste is used to rear BSF and the BSF larvae are used by the same firm as feed in their pig and poultry production. The market-driven model is characterised by using the market for their output and by selling BSF to feed millers or directly to livestock producers. The out-grower business model is characterised by binding arrangements between a small-scale BSF farmer and an established medium to large-scale firm. One third of the BSF producers identified were women. The majority (58.4 %) of the BSF farmers used the cyclic business model, followed by the marked driven model (29.4 %) and only 12.2 % being in out-grower business model. Women producers were dominantly using the out-grower model (75 %).

Keywords: Black soldier flies, business models, gender, livestock feed

Contact Address: Holger Kirscht, International Centre of Insect Physiology and Ecology (icipe), Social Science and Impact Assessment Unit, P.o. Box 30772, 00100 Nairobi, Kenya, e-mail: hkirscht@icipe.org

The influence of drinking water acidification in broilers under Indonesian conditions

Christian Lückstädt, Kevin Teh, Stevan Petrović

ADDCON, Germany

Organic acids, and in particular formic acid and its salts, are well known to improve productivity in animal nutrition. By acting against pathogens, they help to decrease pressure on the animal's immune system, thus more nutrients will be available for productive functions such as growth. The use of acidifiers via the drinking water will therefore not only create hygienic conditions in the water itself but will also lead to improved performance parameters in poultry. This is especially needed during the rainy season, when conditions are severe, and mortality is rising. A recent trial, conducted at a broiler farm under such conditions in Indonesia, tested drinking water acidification with a liquid acidifier consisting of formic acid and sodium formate (ADDCON XL2.0) at a dosage of 0.6 ml/1000 ml drinking water for 8 h a day from day 14 onwards till slaughter, against a negative control. 55,000 birds were randomly selected and divided equally into 2 groups with 27,500 broilers each. Feed and water were available ad libitum. The effects of the acidifier on performance (daily weight gain, feed conversion) as well as productivity index and mortality were examined at slaughter on day 35. The results are given as mean and a confidence level of 95 % was defined for these analyses. Although the water acidification was carried out for 3 weeks only, average daily weight gain and feed conversion were improved significantly ($p < 0.05$) across the whole cycle. Mortality, calculated from the start of the treatment till slaughter, tended to be reduced by almost 25 % ($p < 0.1$). The resulting overall productivity index of the broilers increased by 4.3 % ($p = 0.012$). It can therefore be concluded that drinking water acidification for broilers has beneficial effects on the performance of the birds and may be considered as a low-cost option to improve production parameters. Especially under tropical conditions, this could play a vital role in providing hygienic drinking water and reducing pathogen load, thus having enormous potential as an integral component of a successful biosecurity programme.

Keywords: Acidifier, broilers, drinking water, performance

Contact Address: Christian Lückstädt, ADDCON, Parsevalstrasse 6, 06749 Bitterfeld-Wolfen, Germany, e-mail: christian.lueckstaedt@addcon.com

Response of broiler chicken to different levels of replacement of boiled bambara seeds (*Vigna subterranea*n verdc) for super-concentrate

Mohamed Ahmed

University of Alneelain, Animal Production, Sudan

The objective of the study was to assess the response of broiler chicken to different levels of replacement of boiled Bambara seeds (*Vigna subterranea*n verdc) for super-concentrate. Growth performance and carcass characteristics were studied. Two hundred one-day-old un-sexed Ross (308) chicks were used in a completely randomised design. Bambara seeds replaced super-concentrate at (0, 25, 50, 75, and 100 %). Chicks were randomly divided into five dietary treatments; each of them was further divided into 4 replicates of 10 birds each. The chicks were reared from one- day-old to six week of age in 20 pens (1 × 1 m) with wood shavings litter. The experiment was conducted in an open- sided poultry house. Five iso-caloric and iso-nitrogenous starter and finisher diets were formulated according to National Research Council (NRC, 1994). Feed intake (FI), body weight gain (BWG), feed conversion ratio (FCR) and Protein efficiency ratio (PER) were determined weekly on a pen basis. The results regarding chemical composition of Bambara seeds indicated positive nutritional components as it includes relatively high protein (16 %). Feed intake and body weight gain during starter and grower phase were significantly ($P \leq 0.05$) decreased with the increased of boiled Bambara seeds. On the other hand, finisher and overall feed intake for birds on 25 % replacement were not significantly ($p \geq 0.05$) different when compared to control. Dressing% was significantly ($p \leq 0.05$) reduced for birds at 75 % and 100 % replacement versus those fed other diets. Based on the current findings, it could be concluded that only 25 % super-concentrate can be replaced by boiled Bambara without any deleterious effects on FI, FCR, PER and dressing%.

Keywords: Bambara seeds, broiler performance, carcass

Contact Address: Mohamed Ahmed, University of Alneelain, Animal Production, P.O. Box 12702, 11121 Khartoum, Sudan, e-mail: moha_555@hotmail.com

Effects of dietary supplementation of red yeast (*Sporidiobolus pararoseus*) in mycotoxin contaminated feed on gene expression in the liver of broilers and layers

Kesinee Gatphayak[1], Wanaporn Tapingkae[1], Shahrbanou Hosseini[2], Bertram Brenig[2]

[1]*Chiang Mai University, Dept. of Animal and Aquatic Sciences, Thailand*

[2]*University of Göttingen, Inst. of Veterinary Medicine, Dept. of Molecular Biology of Livestock, Germany*

Mycotoxin contaminations are a global concern in feedstuffs produced by fungi during their development. Toxicities in poultry reduced their production efficiencies, and immune system. Also, histopathological changes in the liver of broilers and layers were observed. By adding mycotoxin binder to the feed to adsorb the toxins, resulted in the mycotoxin passing harmlessly through the animal. In this study, red yeast (*Sporidiobolus pararoseus*; RY) was used as a novel mycotoxin binder in contaminated feed of broilers and laying hens. Gene expression profiles were studied in liver cell by next generation sequencing (NGS) technology. In broiler, liver samples were collected at 35 days after fed with red yeast 0.5 g kg^{-1} (RY0.5, CON), mycotoxin contaminated corn meal 50 ppb (MB50), MB50+RY0.5 and MB50+RY01.0. Five groups of gene were different expressed between RY0.5 and MB50 ($p < 0.01$). Differential expression analysis (DEGs) was found 2 up-regulation genes (TOMM5 and BORCS5) and 1 novel gene for down-regulation (LOC112533251) ($p < 0.01$). In layers, liver samples were collected after fed for 63 days with four different diets: commercial diet (CON), RY1.0, MB100, and RY1.0+MB100. Highly expressed genes were found in the comparisons between the MB100 and the CON group (1,553 genes) followed by between the MB100 vs RY1.0 (1,141 genes), RY0.1+MB100 vs CON (585 genes), respectively. The least expression of genes showed in the comparison of RY0.1 and CON groups, 8 genes. We identified a set of genes in MB100 and in RY1.0+MB100 diet, which play key roles in phase I (e.g. CYP2C23a, CYP2C23b) and phase II (e.g. UGT1A1, GSTO1) detoxification process of xenobiotics, genes involved in antioxidant mechanisms and immune response were also found. The up-regulated genes of both broiler and layer showed the effect of apoptosis, cell proliferations transcription, differentiation and morphogenesis processes in liver which likely provide more comprehensive protection against the toxicity of mycotoxins and promote positive effect on productivity in poultry.

Keywords: Broiler, gene expression, layer, mycotoxin, red yeast

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Comparing milk production and quality by White Fulani and Gudali cows during the dry season in a semi-arid zone of Benin

Yorou N'gobi Douarou, Bossima Ivan Koura, Boya André Aboh

Université Nationale d'Agriculture (UNA), École de Gestion et d'Exploitation des Systèmes d'Élevage, Benin

In sub-Saharan Africa, climate change affects pasture availability and forage nutritional value. During the dry season, animal productivity in terms of milk production is negatively affected. White Fulani and Gudali cows are two dairy breeds introduced in Benin to improve milk production. However, little is known about the performances of these breeds during the dry season, when forage is poor quality. This study aims to compare feed intake and milk production by the two breeds grazing in the same range during the dry season, to identify the breed more likely to sustain milk production in a climate change context. The study was conducted in the semi-arid area of Benin (Kétou region) during the early (S1) and late dry seasons (S2). The hand-plucking method was used to estimate cows' feed intake. Ten cows that gave birth at the beginning of the experiment were monitored, and the milk offtakes were quantified every two weeks. The chemical composition of the milk was analysed using a milkotester (Milkotester Ltd. 49. Hristo Botev St., 4470 Belovo, BULGARIA). Feed intakes was higher ($14.92\,\mathrm{kg\,day^{-1}}$) in White Fulani than Gudali ($13.23\,\mathrm{kg\,day^{-1}}$). There was a significant difference ($p < 0.001$) in the amount of milk produced by the two breeds. At the beginning and the late dry season, Gudali cows produce more milk ($1.72\,\mathrm{L\,day^{-1}}$) than White fulani ($1.22\,\mathrm{L\,day^{-1}}$). Milk from Gudali contained more fat ($5.57\,\%$) than White Fulani ($5.10\,\%$). However, milk protein content was higher ($3.29\,\%$) in White fulani compared to Gudali ($3.11\,\%$). The study showed that the Gudali cows ingested less forage but had higher milk production. However, milk from White Fulani is richer in protein and lactose content. Further studies could investigate the effect of supplementation on dairy performances in the two breeds.

Keywords: Climate change, fat, milk offtakes, protein, sub-Saharan Africa

Contact Address: Yorou N'gobi Douarou, Université Nationale d'Agriculture (UNA), École de Gestion et d'Exploitation des Systèmes d'Élevage, Bénin Ketou, Ketou, Benin, e-mail: ydouarou1@gmail.com

Preference traits of farmers for indigenous local chicken breeds in southern Benin

Mariette Houngbo, Bossima Ivan Koura, Boya André Aboh

Université Nationale d'Agriculture (UNA), École de Gestion et d'Exploitation des Systèmes d'Elevage, Benin

A diversity of ecotypes characterises local chickens in Benin. However, the characteristics of these ecotypes have been poorly documented, yet this information is essential for better valorisation and sustainable conservation of these local avian resources. This study aims to identify local chicken ecotypes' distinctive traits and farmers' preferences for their attributes. The snowball sampling method allowed the sampling of one hundred twenty local chicken farmers keeping one of the four local chicken ecotypes Fulani, Holli, Sahouè, and Koklo yaya. A semi-structured questionnaire was used to collect data on the production system used by farmers and their preferred traits for the ecotype of chickens reared. Farmers were asked to give scores ranging from 1 (most important) to 5 (less important) for each preferred trait, and the preference index (PI) was calculated. According to the farmers, the main distinctive characteristics of the local chicken ecotypes were the size, the format, the growth, and the quality of the eggs. The Fulani ecotype had large size (17.3 %) with big eggs (12.7 %). Holli and Sahouè ecotype had a medium size (10,9 % and 16,5 %) with small egg in Holli. However, the Koklo yaya was of small size (9,1 %). The preference index revealed that the ecotypes Holli and Sahouè were preferred for the high egg-laying rate (PI. 0.95 and 0.73) and the disease resistance capacity (PI. 0.69 and 0.52). Koklo yaya was preferred for its easy handling (3.33) and disease resistance (2.33) traits. Complementary studies could evaluate the comparative disease resistance capacity of the different ecotypes of local chickens in Benin.

Keywords: Fulani, Holli, Koklo yaya, poultry, Sahouè

Contact Address: Bossima Ivan Koura, Université Nationale d'Agriculture (UNA), Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, Campus of Kétou BP 43, Porto-Novo, Benin, e-mail: kouraivan@gmail.com

ID 805

Effect of probiotic microbial culture from maize steep in drinking water of broiler chickens

Ibiyemi O. Opowoye[1], Oluwagbemiga O. Adeleye[2], Fatai A. Adewole[1],
Abiola O. Salako[3], Foluke E. Sola-Ojo[3], Olajide M. Sogunle[2],
Job Olutimehin Atteh[3]

[1]Federal University of Agriculture Abeokuta, IFSERAR, Nigeria

[2]Federal University of Agriculture Abeokuta, Dept of Animal Production and Health, Nigeria

[3]University of Ilorin, Dept. of Animal Production, Nigeria

Effects of probiotic microbial culture isolated from the steep of fermented maize mash on broiler performance, nutrient retention, blood profile, gut microbial profile and carcass characteristics were assessed in a 42-day trial. Drinking water with none or any of three microorganisms isolated from maize steep and included singly or in combinations to give eight treatment groups; Control (C), *Lactobacillus fermentum* (L), *Bacillus substilis* (B), *Saccharomyces cerevisiae* (S), *Lactobacillus fermentum* and *Bacillus substilis* (LB), *Lactobacillus fermentum* and *Saccharomyces cerevisiae* (LS), *Bacillus substilis* and *Saccharomyces cerevisiae* (BS), *Lactobacillus fermentum*, *Bacillus substilis* and *Saccharomyces cerevisiae* (LBS) were administered to 192 day-old broiler chicks in a Completely Randomised Design. The treatments had 3 replicates with 8 birds each. Daily / weekly data were collected from the birds on performance parameters. Experimental diets and excreta droppings were analysed for their chemical constituents and at 42nd day, samples were collected for blood, gut microbial analyses and carcass evaluation. Average daily feed intake values were significantly ($p < 0.05$) higher for birds on experimental treatments with inclusion of various combinations of microbial culture (LS – 73.14 g bird^{-1} day^{-1}, LBS – 72.40 g bird^{-1} day^{-1}, LB – 72.23 g bird^{-1} day^{-1} and BS – 72.02 g bird^{-1} day^{-1}) compared to birds administered drinking water with inclusion of single microbial culture and control groups (L, B, S and C). Only total protein of all biochemical indices assessed was significantly ($p < 0.05$) influenced with the highest value (36.00 g l^{-1}) observed in birds on LB. The experimental treatments significantly ($p < 0.05$) influenced the birds RBC, MCH and MCV. The RBC of broilers on the experimental treatments were highest compared to those on the control treatment. The MCH and MCV for birds on S were significantly ($p < 0.05$) lowest compared to the values obtained in other treatment groups. There was significant ($p < 0.05$) effect of treatment groups on wing yield. The yield in groups LB (8.44 %), L (8.33 %), LS (8.25 %) and LBS (8.13 %) were higher ($p < 0.05$) than other treatment groups but similar to control group. In conclusion, there was no adverse effect of the probiotic microbial culture on broiler chickens.

Keywords: Broilers, drinking water, maize steep, microbial culture, probiotic

Enteric methane emissions of peri-urban dairy farms during the wet season in southern Benin

Panine Yassegoungbe[1], Gaius Sègbégnon Vihowanou[1], Tawakalitu Onanyemi[1], Eva Schlecht[2], Luc Hippolyte Dossa[1]

[1]*University of Abomey-Calavi, Fac. of Agricultural Sciences, School of Science and Technics of Animal Production, Benin*
[2]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

Enteric methane (eCH_4) emitted by ruminant livestock, especially lactating cows, is a major environmental pollutant worldwide. Six pasture-based dairy farm types (FT) were identified in the peri-urban areas of South Benin and characterised as follows: Small-Herds-Zebu cattle (FT1); Small-Herds-Taurine cattle (FT2); Medium-Herds-Zebu cattle (FT3); Medium-Herds-Taurine cattle (FT4); Large-Mixed-Herds-Taurine-Zebu cattle (FT5); and Medium-Mixed-Herds-Taurine-Zebu cattle (FT6). Up to present, there has been no assessment of their eCH_4 emissions. This study was conducted at the peak of the vegetation period, between mid-September and October 2021, to estimate the eCH_4 emissions from different animal categories (bull, cow, steer and heifer) across the different FTs, with one herd selected per FT. In each herd, one animal per animal category was selected and its bodyweight was predicted from its linear body measurements. Subsequently, its grazing behaviour was monitored for three consecutive days. Direct observation of grazing duration, bite counts and hand-plucked bite mass estimation were used to estimate daily feed intake on pasture. The nutrient content and digestibility of the collected feed samples were predicted using near-infrared spectroscopy. Feed dry matter intake (DMI) was estimated as a function of the animal's grazing behaviour and metabolic bodyweight ($kg^{0.75}$). The eCH_4 emission factors (EF) and annual emissions for each animal category were estimated using the IPCC Tier 2 method and compared across FTs. All statistical analyses were performed with R software. EF (kg CH_4/head/year) varied ($p < 0.05$) between FTs for all animal categories, except for lactating cows. It ranged from 8.8 to 9.3 in steers, 9.3 to 10.0 in bulls, 9.0 to 9.3 in heifers, and 9.3 to 9.7 in lactating cows ($p < 0.05$). The lowest EF (10.3) was recorded in bulls followed by steers (15.3) in FT2. The highest eCH_4-emitting lactating cows (399) and heifers (173) were found in FT5, whereas the lowest-emitting lactating cows (72) and heifers (35) were observed in FT1 and FT2, respectively. These preliminary findings suggest that a shift towards small herds of locally adapted taurine cows selected for increased milk production will likely contribute to the reduction of eCH_4 emissions in peri-urban dairy farms of South Benin.

Keywords: Emission factors, feed ingestion, greenhouse gas emissions, pasture-based livestock systems, peri-urban cattle farming

Contact Address: Luc Hippolyte Dossa, University of Abomey-Calavi, Fac. of Agricultural Sciences, School of Science and Technics of Animal Production, 01 BP 526, Cotonou, Benin, e-mail: dolhip@yahoo.com

Effect of *Ocimum gratissimum* on carcass quality of broiler chicken

Eyerin-Ebi H. Japan

Niger Delta University, Dept. of Animal Sciences, Nigeria

Phytogenics (natural growth promoters derived from plant) feed additives are added in poultry diets as appropriate replacement for antibiotics. This experiment was aimed at accessing the effect of *Ocimum gratissimum* extracts on carcass quality of broiler chickens. The specific objectives were to evaluate the possibility of *O. gratissimum* to enhance breast meat and to determine the effect of *O. gratissimum* on organ weight of broiler chicken.

The study was carried out at Niger Delta University Teaching and Research Farm. A total of one-hundred and ninety-five Cobb-500 day-old broiler chicks were randomly distributed into three treatment groups of sixty-five birds each, with five replicates of thirteen birds per replicate. The control group (T1) was given commercial starter and finisher diets, treatment two (T2) was given *O. gratissimum* extract in commercial feed and treatment three (T3) was administered aqueous extract of *O. gratissimum*. The experiment lasted fifty-four days and was arranged in a completely randomised design. Data on carcass weight was collected, weight of different carcass cut-up parts and internal organs was determined by weighing. All data was collected twice (at day 40 and day 54). The data was subjected to one-way analysis of variance and significant differences were identified.

Aqueous *O. gratissimum* extract significantly ($p < 0.05$) improved the final live weight and breast weight of T3 at day 54 (2137.75 and 536.25, respectively), compared to T1 (1684.20 and 395.25, respectively). *O. gratissimum* extract in feed (T2) also significantly enhanced ($p < 0.05$) live weight and breast meat weight (1858.80 and 420.50, respectively), compared to T1. There was no significant difference ($p > 0.05$) in organ weights of each treatment.

The results showed that *O. gratissimum* improved breast meat and had no adverse effect on organs, such as enlarged organs.

Keywords: Breast meat, broiler chicken, carcass quality, *Ocimum gratissimum*

Contact Address: Eyerin-Ebi H. Japan, Niger Delta University, Dept. of Animal Sciences, Km3 512101, Igwuruta Road, 511101 Port Harcourt, Nigeria, e-mail: japaneyerinebi@gmail.com

Bacterial community succession in the intestinal tract of broiler chicken raised in in open-sided house system

Waleed Al-Marzooqi

Sultan Qaboos Universit, Animal & Veterinary Sciences, Oman

This study assessed the relative abundance of the intestinal microbial composition in duodenum, jejunum, ileum, and cecum of broiler chicken (Cobb500) raised in an open-sided house fed a nonmedicated corn-soybean meal diet from 0–35 days of age. A total of 1,179,68 sequences of 16S rDNA-based analysis were clustered into 253 operational taxonomic units at the 97 % sequence similarity which identified seven phyla and twenty-six Families. Of the total sequences, Firmicutes constituted a dominant phylum in duodenum, jejunum, ileum and cecum, accounting for 96.4 %, 88.8 % and 96.8%; respectively. The least dominant were Tenericutes and Thermi phyla, ranging from 0.12–0.01 % in the same gut order. At the Family level, Lactobacillaceae was dominant in duodenum, jejunum, ileum and cecum accounting for 73.87 %, 43.30 %, 77.81 % and 46.30%; respectively of the total sequences. Both Ruminococcaceae and Lachnospiraceae were the most prominent Families, accounting for 30.8 % and 28.61%; respectively of the total sequences of the reads obtained from the four intestinal sections. One of the most intriguing findings of this study is that, in addition to differences in relative abundance, the statistical comparisons of the 16S rDNA libraries of microbial communities revealed that each gut segment harbors its unique bacterial community. This was supported by Principal Coordinate Analysis (PCoA) which showed a clear separation of bacterial communities between jejunum and cecum samples compared to those from duodenum and ileum, suggesting some similarity in microbial community structure between the duodenum and ileum. The results obtained characterises the development of the chicken intestinal microbiota over time period under naturally ventilated housing system. The study provides unique insight into bacterial community and relative abundance of these were quite diverse and significant differences in microbial community composition from different intestinal segments were identified.

Keywords: 16S rDNA, broiler, chicken, house, intestine, microbiota

Contact Address: Waleed Al-Marzooqi, Sultan Qaboos Universit, Animal & Veterinary Sciences, PC 123 Al- Khod, Muscat, Oman, e-mail: walmar@squ.edu.om

ID 630

Evaluation of alternative feed resource in intake, milk yield and milk quality of lactating West African dwarf goats

Gladys Ibhaze, Gbenga Ogunjemite, Oluwaseun Adebayo

Federal University of Technology, Animal Production and Health, Nigeria

Dry season feeding is a major challenge to ruminant farmers and animals as this results in low productivity, death of the animals and economic loss to the farmer. Hence, the need to search for alternative sustainable feed resources in circumventing this occurrence. Sixteen West African Dwarf (WAD) does were fed cassava peel-*Gmelina arborea* leaves silage to evaluate their intake, milk yield and milk constituents. Four experimental diets were anaerobically made from varying proportions of cassava peel (CSP) and *Gmelina arborea* (GML) leaves as shown; 100GML, 90GML+10CSP, 70GML+30CSP and 50GML+50CSP. The does were divided into four (4) groups of four animals per group as each animal served as a replicate for each treatment in a completely randomised design (CRD). The experiment lasted for 56 days. Data on voluntary feed intake was collected daily while the milk yield was obtained once a week. Results showed significant ($p < 0.05$) differences in intake, feed conversion ratio, and milk yield. Goats fed 50GML+ 50 CSP silage had the highest (520.96 g day^{-1}) intake and the least (289.23 g day^{-1}) was observed in goats fed 100GML. Highest (2.28) FCR was observed in goats fed 100GML while the least 2.07 g day^{-1}) was observed in goats fed 50GML+ 50 CSP silage. The milk yield was highest (323.51 g day^{-1}) in goats fed 50GML+ 50 CSP silage while the least (192.89 g day^{-1}) was observed in goats fed 100GML. Milk constituents did not vary significantly ($p > 0.05$) as values ranged from 3.57–3.86 % for protein while fat, lactose, ash, total solids, solids-not –fat varied from 4.02–4.32 %, 4.11–4.59 %, 0.71–0.89 %, 12.95–13.18 % and 8.74–8.98 % respectively. Milk energy did not differ ($p > 0.05$) among treatment groups as the values ranged from 3.16–3.24 (MJ kg^{-1}). Negative but significant ($p < 0.05$) correlation coefficients existed between mean milk yield and milk components. Values ranged from r=0.29* between mean milk yield and total solid to r=0.51* for lactose. Positive and significant ($p < 0.05$) relationship were observed between protein and total solid (0.71*) and between fat and total solid (0.59*). Conclusively, feeding cassava peel-*Gmelina arborea* leaves silage at equal proportions (50:50) as off season feed could best sustain and support milk production in WAD goats.

Keywords: Cassava peel, *Gmelina arborea*, lactating, milk constituents, milk yield, WAD goats

Grazing behaviour of the endemic lagune cattle in sub-humid savannah of Benin

Elie Sonon, Bossima Ivan Koura, Armand Bienvenu Gbangboche

National University of Agriculture, Management and Exploitation of Livestock Systems, Benin

The indigenous Lagune cattle, a trypanotolerant breed, is a good candidate when searching for a sustainable breed to meet the ongoing environmental changes. The breed could be kept like small ruminants, tethered in grasslands, or free grazing. Objectives. A study was conducted to assess the grazing behaviour of Lagune cattle under two grazing systems, free grazing and tethered. Two farms in free-roaming and 02 others in the tethered system were selected, in the original belt of the Lagune cattle, the agroecological zones of Valley and Pobe. The step-point method was used to assess species diversity in the grazing lands through their frequency and specific contribution. 03 cows were monitored while grazing during 03 consecutive days in each farm. The grazing itinerary and grazing activities were registered allowing to calculate grazing length and duration. In the two AEZs, 133 plant species belonging to 27 families were recorded. The Lagune diet consisted mainly of herbs; a total of 23 forage species from 14 families were grazed. Most of the species belong to the families of Poaceaes (34.78 %), Convolvulaceaes (8.7 %), and Euphorbiaceas (8.7 %). Fats contributed significantly ($p < 0.001$) less to the diet in the free grazing system (59.84 %) than in Tethered one (70.70 %). *Panicum maximum* (16.22 %) and *Mariscus cylindristachyus* (12.32 %) contributed the most to the diet. The study suggests that Lagune cattle are grazers, and free grazing allows better utilisation of the forage species and the best growth performances. Further studies could investigate diet selection and nutritional balance of the indigenous Lagune cattle.

Keywords: Average daily gain, forage selection, genetic resources conservation, intake, sustainability, West Africa

ID 643

Genomic characterisation of two South African composite breeds in comparison to their base breeds

Phillipine Sithole, Este Van Marle-Köster, Simon Lashmar

University of Pretoria, Dept. of Animal Science, South Africa

South Africa (SA) exhibits great agricultural and ecological diversity, including extreme and ever-changing production environments that will necessitate adaptability and efficiency of animal genetic resources in the future. Through complementarity and heterosis, SA composite breeds combine the superior productivity of exotic taurine breeds with the adaptive and maternal traits of indicine and local Sanga breeds. Apart from the predominant composite (e.g., Bonsmara), numerically smaller composite breeds have not been characterised as well (neither on phenotype nor genotype-level) despite their contributions to local beef production. The aim of the study was to perform a genome-wide characterisation of the genetic diversity and population structure of two SA composite breeds, namely the Santa Gertrudis (SGT) and Simbra (SIM), and their base breeds, namely the Brahman (BRA) and Simmentaler (SMM). A total of 684 animals (BRA = 182, SMM = 261, SIM = 172, SGT = 69), genotyped with the Illumina® Bovine LD v.2 SNP genotyping panel (7 421 quality-filtered SNPs), were available. The average minor allele frequency (MAF) ranged from 0.182 (BRA) to 0.332 (SIM). The observed heterozygosity (HO) indicated the highest level of genetic diversity for SIM (HO = 0.432) and the lowest level for BRA (HO = 0.319). The fixation index (FST) values revealed the most genetic differentiation between the BRA and SMM breeds (FST = 0.208). Conversely, the SIM and SMM were the least differentiated (FST = 0.041). Principal component analysis (PCA) and model-based clustering (admixture) distinguished the breeds according to ancestral origin and breed development. PCA clustered all the SGT animals in one cluster separate from the others. At K=2, the taurine and indicine ancestral contributions towards the SIM breed was illustrated and reflected the originally intended composition of the breed (i.e., 5/8 SMM and 3/8 BRA). The estimated effective population sizes (Ne) in the last 12 generations ago ranged from 215 (SGT) to 316 (SMM), indicating a higher risk of inbreeding for SGT if not managed carefully. The results presented an insight into the genome-level diversity present in two smaller composite breeds and will assist in making more informed breed management and selection decisions for future sustainable use.

Keywords: Beef cattle, composite breeds, genetic diversity, SNP panel

Nutrient digestibility and blood profile of broiler chickens fed fermented sweet orange peel-based diets

Esther Taiwo[1], Oluwabiyi Oluremi[2], Kenan Orayaga[3]

[1]*Swedish University of Agricultural Sciences, Dept. of Animal Breeding and Genetics, Germany*
[2]*The National University of Lesotho, Dept. of Animal Science, Lesotho*
[3]*Federal University of Agriculture, Dept. of Animal Nutrition, Nigeria*

The research aimed to determine the nutrient digestibility and blood profile of broiler chickens fed biodegraded sweet orange peel-based diets in Nigeria. The sweet orange peels were obtained from retail sellers while fresh rumen content was procured from a government abattoir. Rumen content was mixed with water in the ratio of $1\,\text{kg}:1$ litre, and the resultant mixture was sieved to obtain rumen filtrate (RF). The rumen content was mixed with sweet orange peels at the ratio of 1 litre : $2.5\,\text{kg}$ respectively. The mixture was then fermented for 48 hours, sun-dried, milled, and incorporated into the broiler diets at starter and finisher phases as a replacement for maize at levels of 0 % (T1), 5 % (T2), 10 % (T3), 15 % (T4) and 20 % (T5). The experiment involved a fifty-six-day feeding trial, where a hundred and fifty-day-old chickens were randomly assigned to five dietary treatments, and each was replicated three times in a completely randomised design. The results showed that the coefficient of digestibility of dry matter, crude protein, crude fibre, ether extract and nitrogen-free-extract did not differ significantly ($p > 0.05$) among the treatment groups, while, as retention differed significantly ($p < 0.05$) across the treatment groups haematological indices; haemoglobin, red blood cell (RBC), packed cell volume, mean corpuscular volume (MCV) and mean corpuscular haemoglobin (MCH), did not differ significantly ($p > 0.05$) across the dietary groups, white blood cell (WBC) and mean corpuscular haemoglobin concentration (MCHC) varied significantly ($p < 0.05$), serum indices; total protein (TP), globulin, glucose, cholesterol, and alkaline phosphatase, were significantly affected ($p < 0.05$) by the experimental diets, while albumin, aspartate transaminase, and alanine transaminase did not differ significantly ($p < 0.05$) across the dietary groups. Sweet orange peel-based diets can replace maize up to 20 % without affecting nutrient digestibility or having any deleterious effect on the blood parameters of broiler chickens.

Keywords: Blood profile, broiler chickens, fermentation, nutrient digestibility, rumen filtrate

Contact Address: Oluwabiyi Oluremi, The National University of Lesotho, Dept. of Animal Science, Roma, 180 Maseru, Lesotho, e-mail: oiaoluremi@yahoo.com

ID 440

Livestock and income, livelihoods and resilience

Online posters

Crop-livestock integration in urban agriculture: Implication for urban food security in Ghana

Faizal Adams[1], James Osei-Mensah[1], Quaye Jonathan[1], Amos Mensah[1], Robert Aidoo[1], Harald Kaechele[2], Seth Etuah[1]

[1]*Kwame Nkrumah University of Science and Technology (KNUST-Kumasi), Dept. of Agricultural Economics, Agribusiness and Extension, Ghana*

[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Inst. of Socioeconomics, Germany*

The severity of food insecurity in urban regions is illustrated by factors such as growing food prices, rapid urbanisation, and the lack of rural areas' capacity to feed the city's population. Urban agriculture has recently gained popularity as a means of addressing urban food poverty, but few studies have specifically examined the possibilities of integrated urban crop-livestock (ICL) systems. The purpose of the study, therefore, was to analyse the impact of ICL on the food security of urban households in the Kumasi Metropolis of Ghana. Data were solicited from 430 households through a multi-stage sampling technique. The study uses the household food insecurity access scale (HFIAS) and household dietary diversity score (HDDS) to measure the food security situations of urban households. Further, a seemingly unrelated regression equation (SURE) was used to examine the precursors of food security among urban households while the inverse probability weighted regression adjustment (IPWRA) model that corrects selection bias was used to determine the impact of integrated crop-livestock farming on food security of urban households. Findings of the food security indices show a low prevalence of food insecurity among the urban households who practised integrated crop-livestock production systems compared to counterpart households engaged in no-farm, crop-only, and livestock-only producers. The SURE reveals a diverse range of covariates that affect the food security status of non-farm households, crop-only farm families, livestock-only households, and integrated crop-livestock producers, suggesting special considerations to target the various urban households towards the promotion of urban agriculture in the study area. The IPWRA shows better access to food and dietary diversity for urban residents engaged in integrated crop-livestock farms compared to non-farm, only crops and only livestock farm households in the study area. The study presents pertinent recommendations and explores the consequences of the findings.

Keywords: Dietary diversity, farming systems, impact assessment

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ID 3

Diversity of sheep farming systems in the urban and peri-urban areas of southern Benin

Codjo Esteban Hénoc Medenou[1], Eva Schlecht[2], Luc Hippolyte Dossa[1]

[1]*University of Abomey-Calavi/ Doctoral School of Agricultural Sciences and Water, Fac. of Agricultural Sciences, Benin*

[2]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

Sheep farming is widely practised in West Africa, where it is associated with high economic and social values. This activity has spread in and around urban areas to meet the increasing urban demand for sheep meat. In addition, the sheep is of religious importance for Muslims in the Eid el Kebir annual celebration (Tabaski). Since little is known about how sheep farms operate in the current context of rapid urbanisation in Benin, this study aimed to characterise and typify sheep production systems in urban and peri-urban areas in southern Benin. Socio-economic and management practices data were collected through a structured questionnaire from a total of hundred farmers selected with the snowball sampling approach. R statistical software was used for Multiple Correspondence Analyses (MCA) followed by a Hierarchical Classification of Principal Components (HCPC) to establish a farm typology based on the acquired data. Comparisons between farm types were done using the nonparametric Chi-squared test for qualitative variables and the Kruskal-Wallis test for continuous variables. The results revealed 6 types of sheep farms which differed in type of housing, fattening unit, location, and proportion of rams in the herd. Irrespective of the farm type, all interviewed farmers were men. Animal husbandry was the main source of income for members of 3 out of the 6 farm types ($p < 0.001$). Overall, the median herd size was 29 animals whereas the median number of sheep fattened in the previous year was 15 with a significant variation between farm types ($p < 0.001$). The majority of the farms (72 %) practised both breeding and fattening. Zero-grazing management (61 %) and feeding concentrate feeds (58 %) were practised widely but varied significantly across farm types ($p < 0.001$). While in almost all peri-urban farms (90 %) sheep manure was used to fertilise the crops fields, more than half of the urban farms reported manure disposal problems. Improper manure disposal is not only an environmental problem but also an economic loss. It may, therefore, undermine the sustainability of these farming systems which are undergoing intensification to meet the need of urban consumers throughout the year.

Keywords: Sheep fattening, small-ruminants, sub-Sahara Africa, typology, urbanisation

Contact Address: Luc Hippolyte Dossa, University of Abomey-Calavi, Fac. of Agricultural Sciences, School of Science and Technics of Animal Production, 01 BP 526, Cotonou, Benin, e-mail: dolhip@yahoo.com

Feasibility of improved silvopastoral systems in the Caribbean region of Nicaragua

Rein van der Hoek[1], Martín Mena Urbina[2], Jenny Wiegel[2], Marlon López[2]

[1]*The Alliance of Bioversity International and CIAT, West Africa, Senegal*
[2]*The Alliance of Bioversity International and CIAT, Nicaragua*

In Nicaragua, land use change and agriculture cause 80 % of total greenhouse gas emissions, of which more than half are from livestock. Livestock farming occupies almost 50 % of total land area and is a major cause of forestland conversion, especially in the Caribbean region covering over half of the national territory, with 89 % of the country's forests and the highest proportion of poor people. The conversion of forests to agricultural land uses and inadequate pasture management have severe environmental impacts, including land degradation, biodiversity loss and exacerbation of flood-drought cycles.

FAO requested a feasibility study of different scenarios (Business as Usual-BAU versus silvo-pastoral interventions-SPS) of investments in silvopastoral components (such as live fences, fodder banks, regeneration of trees in pastures) and improved pastures of small and medium livestock farms. For each scenario the biophysical, environmental and climate impacts - nitrogen balance, land and water requirement, greenhouse gas (GHG) emissions and carbon stock changes - were analysed using the rapid ex-ante assessment tool "CLEANED". Net income from livestock production and costs of silvopastoral systems with different tree types and densities were assessed. Internal rate of return (IRR) and payback period were calculated based on an investment life of 12 years.

All SPS scenarios show increased carrying capacity, productivity (by 30–50 %) and reduced GHG emission intensities (by 25–50 %). The increased productivity in SPS scenarios potentially frees land by up to 25 % (mainly pastures) for restoration and/or reforestation. Water use per kg of milk decreases by 50. The proposed investments lead to an increased carbon accumulation of 5.1 to 7.8 t CO_2 e ha^{-1} and an IRR of 9 % to 28 %. Carbon sequestration in small farms exceeds emissions by almost 4 t CO_2 e ha^{-1} and fully compensates emissions in medium farms.

The proposed interventions do not provide sufficient nitrogen to substitute the increased nutrient uptake by grasses and other crops, leading to increasingly negative nitrogen balances of up to 53 kg ha^{-1}. To ensure long-term sustainability, this will have to be compensated with nutrient input into the systems, like increasing the proportion of leguminous trees and associating grasses with herbaceous legumes.

Keywords: Caribbean region, CLEANED tool, feasibility study, improved silvopastoral systems, Nicaragua

Contact Address: Rein van der Hoek, The Alliance of Bioversity International and CIAT, West Africa, Dakar, Senegal, e-mail: r.vanderhoek@cgiar.org

Screening for innovations that address sustainability trade-offs in Kenyan livestock systems

Louis Philipp Schwarze[1], Thomas Daum[1], Wellington Mulinge[2], John Mburu[3], Regina Birner[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*Kenya Agricultural and Livestock Research Organization, Socio Economics and Policy Development, Kenya*
[3]*University of Nairobi, Dept. of Agricultural Economics, Kenya*

The consumption of livestock products in Africa is soaring in response to population growth, urbanisation and rising incomes, which will trigger a livestock revolution leading to the intensification and up-scaling of livestock systems. While this creates economic opportunities for livestock keepers and could alleviate pervasive nutritional deficiencies, it may come with a "long shadow", causing challenges such as rising greenhouse gas emissions, zoonotic diseases, land-use changes, marginalisation of smallholders and environmental pollution. Innovations that minimise trade-offs and foster synergies between sustainability dimensions could help to harness the potentials of a livestock revolution while minimising its long shadow. Yet, little is known to which extent existing innovations address these sustainability trade-offs.

Taking Kenya as a case study, we explored sustainability trade-offs of typical poultry, dairy and beef livestock systems. Then, we screened for available innovations and assessed their potential to address trade-offs. Data was collected in 11 expert focus group discussions comprising 49 key informants from livestock-related research and advisory institutions using participatory matrix scoring and listing.

Matrix scoring results underscore that small-scale beef and dairy systems are highly relevant for nutrition and local livelihoods but associated with trade-offs like land degradation, land use change and vulnerability to climate change. Key trade-offs in poultry systems are low economic resilience, overuse of antibiotics and food safety risks. In total we identified 47 innovations of which most (75 %) are narrowly geared to enhance productivity through intensification. These innovations often implicitly improve local livelihoods (49 %) but leave environmental trade-offs such as land use change, environmental pollution and GHG-emissions as well as issues like food safety and animal welfare largely unaddressed (5–10 %). Only very few innovations, for example biodigesters and insect-based feeds, are explicitly trade-off minimising while others such as chicken cages or pure breeds further exacerbate existing trade-offs. We recommend further examination of the livestock innovation systems to identify obstacles for trade-off minimising innovations.

Keywords: Innovation, livestock revolution, livestock systems, livestock's long shadow, trade-off analysis

Contact Address: Louis Philipp Schwarze, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Bergweg 6a, 34471 Volkmarsen, Germany, e-mail: louis.schwarze@uni-hohenheim.de

Profitability analysis of a silvo-pastoral system in Colombia: Economic and environmental benefits

Danny Fernando Sandoval, Jesús Fernando Florez, Karen Enciso, Mauricio Sotelo, Stefan Burkart

The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia

Cattle production systems generate considerable environmental impacts, among which deforestation and the emission of methane by ruminants stand out. Consequently, technological innovations within this sector must be focused on achieving sustainable production in both economic and environmental terms. Silvo-pastoral systems (SPS) as a productive alternative allow an increase in economic yields while generating environmental benefits and ecosystem services. This study is aimed at evaluating the environmental-economic benefits of implementing two SPS in Colombia, namely (i) *Urochloa brizantha* cv. Toledo + *Leucaena leucocephala* and (ii) *Urochloa* hybrid cv. Cayman + *Leucaena leucocephala*. They are compared with two monoculture systems (M), namely (i) *Urochloa brizantha* cv. Toledo and (ii) *Urochloa* hybrid cv. Cayman. The evaluation comprises two components, an economic evaluation, which estimates the potential improvements in profitability of meat production in the SPS through with the cost-benefit analysis methodology, and an environmental evaluation, which estimates the economic value of the environmental benefits and ecosystem services generated in the SPS. This resulting economic-environmental value is integrated into the economic evaluation, achieving a sustainability analysis of the studied SPS. The results show better profitability indicators for the SPS, such as the net present value, internal rate of return, and benefit-cost ratio, which further improve when the results of the environmental evaluation are incorporated. Likewise, SPS are less sensitive to external shocks. Regarding the environmental values, economic values for the reduction of methane emissions of US$6.12 per cattle and for the microclimatic regulation of US$ 2,026 per ha are estimated for the SPS. The results thus suggest an improvement in economic profitability added to the value of ecosystem services and environmental benefits that they incorporate. This type of evidence can be used to promote the adoption of SPS in regions with low productivity and high deforestation rates, such as in large parts of Colombia.

Keywords: Ecosystem services, heat stress, methane emissions reduction

Contact Address: Stefan Burkart, International Center for Tropical Agriculture (CIAT), Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Performance and livestock producers' integration into cattle and pig farmer groups in the northwest highlands of Vietnam

Aura Bravo[1], Thinh Nguyen Thi[2], Phuong Nguyen Thi Minh[2], Natalia Triana-Angel[1], Cuong Tran The[3], Hung Pham-Van[3], Nga Nguyen Thi Duong[3], Huyen Nguyen Thi Thu[3], Karen Marshall[4], Stefan Burkart[1]

[1]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia*
[2]*International Livestock Research Institute (ILRI), Vietnam*
[3]*Vietnam National University of Agriculture (VNUA), Vietnam*
[4]*International Livestock Research Institute (ILRI), Kenya*

Farmer groups in Vietnam have undergone considerable transformations following the enforcement of the 2012 Law on Cooperatives. Under the new regulations, the old cooperative model became obsolete, which led to the disintegration or stop operation of numerous organisations. This gave way to a developing process of new forms of association in agricultural production, a field open to exploration. Within an evolving economy with greater exposure to international markets, adopting a scheme based on collective voluntariness reveals a challenging path for agricultural production's social organisation, even more so if the individual perspectives of stakeholders on the performance and convenience of these groups are considered. Previous interventions have promoted the creation of farmer groups in Vietnam's Northwest Highlands (NWH) to foster associativity, facilitating connection to markets and economies of scale for services, technologies, and knowledge transfer to livestock farmers. This research thus provides an assessment of the functioning and capacities of farmer groups engaged in cattle and pig production. To this end, five components were defined based on tools commonly used for strengthening farmer groups: 1) democratic, inclusive, and participatory management, 2) service offer and capacity building, 3) economic and financial sustainability, 4) managerial and administrative capacity, and 4) market connections and trading capacity. This approach integrates the analysis of behavioural elements from members, non-members, men, women, and local authorities on the perceived trust and commitment to participate in existing forms of cooperation. Information was collected through focus groups discussion and key informant interviews. The findings are currently being analysed and will allow researchers to design interventions aimed at strengthening farmer groups. They will too serve as input for current efforts to develop innovative models to deliver and scale innovations towards sustainable livestock production, replicable in other regions.

Keywords: Associativity, innovation delivery, livestock groups, strengthen farmer groups

Village livestock promoters: Effective, sustainable and scalable supporter for small-scale dairy producers in Nepal?

Nils Teufel[1], Varijaksha Padmakumar[2], Braja Swain[2], James Rao[1], Isabelle Baltenweck[1]

[1]*International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kenya*
[2]*International Livestock Research Institute (ILRI), India*

In Nepal, as in many developing countries, small-scale dairy production has been growing strongly as incomes rise and diets become more diverse. Yet the productivity of dairy production has remained low and its potential for livelihood improvements unfulfiled. The traditional extension system, never very strong on livestock production, has been receiving ever less funding, while the private sector provision of services and inputs has increased greatly, both in reach and diversity of products. However, promotional activities are mostly focused only on specific products and their individual benefits. Approaches for supporting farmers in their efforts to improve overall productivity and profitability of their dairy production are often missing.

The OneCGIAR initiative on Sustainable Animal Productivity for Livelihoods, Nutrition and Gender (SAPLING) is attempting to address this issue by piloting interventions to establish village-level livestock agents in several countries. In Nepal, these agents are known as "Village Livestock Promoters" (VLP) and are located in the eastern lowlands, where dairy production, mainly with buffaloes, is most important. They are linked to local dairy cooperatives and administrations, which provide them with financial support for livestock development work, such as farmer training and recording data for a national genetics database. However, for sustainability VLPs are expected to establish their own businesses, providing services and inputs to their farmers, based on extension activities such as ration balancing with ILRI's On-Farm Feed Advisor and advice on fertility improvement is expected to increase demand.

First results documenting the process and its effects highlight the approach's opportunities, but also emphasise the importance of ensuring active support by all stakeholders. For instance, dairy cooperatives in the study area are not always strong enough to support livestock development and some local administrators do not attach a high priority to dairy farmers. Also, careful screening of VLP candidates during their identification is essential to ensure their interests and skills are aligned with the role's objectives. The roll-out of the VLP intervention will be staggered with a randomised assignment to training batches to enable the causal determination of the approach's effects.

Keywords: Business development, Nepal, small-scale dairy, sustainable extension

Contact Address: Nils Teufel, International Livestock Research Institute (ILRI), Policies, Institutions & Livelihoods (PIL), Kabete, Old Naivasha Road, PO Box 30709, 00100 Nairobi, Kenya, e-mail: n.teufel@cgiar.org

ID 828

Intensive grazing system making possible a profitable and sustainable livestock production in the dry tropic of Mexico

Adriano Silva[1], Rosa Noemi Jauregui[2], David Florian[1]

[1]*Papalotla, R&D, Brazil*
[2]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*

Oaxaca state in Mexico faces important challenges in terms of development. It is the third poorest state with 67 % of the population below the poverty line. One reason for that is the extreme climatic condition with very low annual precipitation (less than 700 mm) and high temperatures. It is normal for the region to stay more than 200 days without rain. Despite this challenging scenario, Oaxaca state has 2.8 millions of potential hectares for cattle grazing. Currently, it has more than 1.6 million animals. More than 70 % of livestock is extensive and composed of small production units, with precarious level of technology. The main limitation factors for development of livestock in the region are low reproductive performance, lack of infrastructure and low production of grains and forage to feed the animals. An experiment with 20 animals has been conducted since 2019 in Oaxaca State at Papalotla Group research centre to explore the cattle production potential in an intensive grazing system. The experiment covers an area of 10 hectares, divided into 40 paddocks, with a grazing period of 1 day per paddock. The grass species used in this experiment are two *Brachiaria* hybrids developed by CIAT (International Center for Tropical Agriculture) in a public-private partnership with Papalotla Group. Camello is a highly drought tolerant forage sowed in the paddocks, while Cobra that produces high amount of forage under irrigation and fertilisation, was offered to the animals during dry seasons in a cut-and-carry system mixed with *Cratylia argentea*, a shrubby perennial tropical legume. Both hybrids have up to 18 % of protein crude and around 70 % of dry mattrer digestibility. The results so far show an average daily weight gain of 0.802 kg ha^{-1} (2019–2022). Animals kept gaining weight even during dry season when normally the local producers lost around 10 % of their animals. Even though the investment to implement the system is relatively high, with the right technology, using highly adapted improved pastures and intensive grazing methods, it is possible to have a profitable business in the region. Once installed, the economic analysis showed a positive balance with an annual income around US$20k (10 ha) and a net profit around 25 %, depending on costs and sales price.

Keywords: *Brachiaria* hybrid, grazing system

Contact Address: Adriano Silva, Papalotla, R&D, Rod Dr Antonio Luiz Moura Gonzaga, 647, Casa A14, 88048-300 Florianopolis, Brazil, e-mail: asilva@grupopapalotla.com

Duck-rice-fish system without insecticides: An useful organic agricultural value chain in rural north Vietnam

Thi Minh Nguyen[1], Viet Ly Le[2], Margaret Gill[3]

[1]*Animal Husbandry Association of Vietnam (AHAV) (retired), Vietnam*
[2]*National Institute of Animal Science (NIAS) (retired), Vietnam*
[3]*The Macaulay Institute, United Kingdom*

There is an urgent problem of contaminated feedstuff for human or animal by excessive use of insecticides for producing agricultural products, which can be a dangerous impact on health by immediate or hidden toxification. This serious problem is not only in Vietnam, but also in tropical developing countries.

This study therefore aimed at evaluating how to prevent or avoid the use of insecticides by keeping local ducks, fish and rice symbiotically. These systems could guarantee for safety agricultural products and environmental protection without insecticides, also help poverty alleviation for poor farmers.

Experiments were conducted with Co ducks in the symbiotic systems of duck-rice (DR); grower duck-fish-rice (DFR); layer duck-fish-rice (LDFR); fish-rice (FR); and compared to a control using insecticides for growing rice (R).

First, a technical test was done and results showed that rice production in R and DR systems were not different: 4053 and 4036 kg ha^{-1} resp.; minimum residue limit of insecticides (MRL) was 3.9 and zero g kg^{-1} of dry paddy resp. Then the systems of R; FR; DR; DFR and LDFR with different number of ducks/hectare were compared. Results showed that rice yields were similar (4125; 4195; 4115; 4479 and 4743 kg ha^{-1}) between R; FR; DR; DFR and LDFR systems resp. MRL were 4.2 g kg^{-1} of dry paddy; 0.05 g L^{-1} of water in R system and zero in others. Net benefits were +1.94; +8.54; +9.91; +44.22 and +55.64 million VND ha^{-1} in R; FR; DR; DFR and LDFR systems resp. at the exp. time.

The above systems proved useful and many poor farmers have been designing the none-insecticides systems for their cultivation for many years and expand up to now. Furthermore, many poor women became stakeholders in alleviation of poverty.

Keywords: Alleviation of poverty, Co duck, duck-fish-rice systems, experiments, insecticides

Contact Address: Thi Minh Nguyen, Animal Husbandry Association of Vietnam (AHAV) (retired), Thon Noi 3, Duc Thuong, Hoai Duc, Hanoi, Vietnam, e-mail: minhthach55@gmail.com

Information exchange patterns and technology adoption behaviour of cattle farmers in the Colombian Amazon

Anja Lienert[1], Stefan Burkart[2], Christian Lippert[1]

[1]*University of Hohenheim, Production Theory and Resource Economics, Germany*
[2]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia*

Colombia's cattle sector, characterised by extensive production systems, plays an important role in the national economy, contributing 19.8 % to the agricultural GDP and providing employment and income to around one million people. However, the sector is associated with low productivity and negative environmental impacts such as land degradation, greenhouse gas emissions, and deforestation. This is particularly true in the Caquetá Department, located in the Colombian Amazon, which has the country´s fifth largest cattle herd and the highest deforestation rate. Although efforts have been made in recent decades to introduce improved production practices to intensify cattle farming in a sustainable manner (e.g., improved forages or silvo-pastoral systems), corresponding adoption rates remain low.

While several studies have analysed the cattle sector in Caquetá and have identified key adoption barriers, such as poor access to finance, inputs, technical assistance, and knowledge, the importance of interconnections, and information exchange between different actor groups in facilitating innovation diffusion, has received only marginal attention. There is a broad consensus that the structure and composition of social networks can affect information flows, learning processes, capabilities, preferences, and decision-making processes and that social networks can both facilitate and impede access to information. To address the identified knowledge gap, a social network analysis (SNA) using egocentric network methods will be conducted in June 2023 with 150 cattle farmers in the Caquetá Department to study the structure, composition, and strength of personal information exchange networks as well as their influence on technology adoption behaviour. Information will be elicited about the interviewed farmers' relationships with other farmers, and with other actors such as input and service providers, buyers, extension agents, researchers, and NGO staff. First results will be presented during the Tropentag. Heterogeneous patterns of information exchange are expected to exist in the Caquetá Department, depending on, among others, the degree of remoteness of the farmers. It is also expected that farmers with larger, more diverse, and more fragmented networks are more likely to adopt improved practices. The findings will be useful for designing more context-specific policies to improve information flows and promote the sustainable transformation of the cattle sector.

Keywords: Caquetá, Colombian Amazon, ego-centric network analysis, extensive cattle husbandry, sustainable intensification, technology adoption

Contact Address: Anja Lienert, University of Hohenheim, Production Theory and Resource Economics, Stuttgart, Germany, e-mail: a.lienert@cgiar.org

Impacts of urbanisation and climate change on the livelihood of livestock owners in the Cholistan desert, Pakistan

NUMAN ARSHAD[1], MARION REICHENBACH[2]

[1]University of Göttingen and Kassel, Department of Organic Agriculture, Pakistan
[2]University of Kassel / Georg-August-Universität Göttingen, Animal Husbandry in the Tropics and Subtropics, Germany

Climate change and urbanisation are emerging issues that drive changes in livestock production and the livelihood of people living from it in Pakistan. This study aims to document the impacts of urbanization and climate change on the livelihood of livestock owners near the city of Yazman Mandi in the Cholistan Desert of Pakistan. The main objectives of the study are to 1) give an overview of local livestock production, resources availability, and rural-urban linkages; 2) understand how urbanization impacts their livelihood; 3) inquire if climate change impacts livestock health and production. One survey (n=100) and six focus group discussions were conducted in 13 villages surrounding Yazman Mandi. Respondents were selected through random sampling and segregated into an urban (Urb) and a rural (Rural) group (G). This was based on nearness and travel frequency to the city. A mixed methods approach was applied to collect data which was analyzed using descriptive statistics, independent T-test, and Pearson Chi-square test using SPSS-29. Results showed that respondents in cluster G-Urb were more educated, had diversified sources of income and achieved better selling prices for dairy products and live animals. For respondents in cluster G-Rural, by contrast, livestock was the main source of income, their herd sizes were large and they were more dependent on the exploitation of natural resources for their livelihood. Both groups were facing deficiency of pasture and water resources, and high disease incidence in cattle and small ruminants - all attributed to climate change effects. Furthermore, both groups had significant occurrences of animal reproductive issues, low milk and meat production, and heat stress. There is a need to educate and make farmers aware of modern livestock-keeping methods. Training should be organized to enable farmers counteract adverse climate change effects. This study will help students of the related fields, as well as private and government agricultural institutions to better understand changes in livestock-based livelihoods under the impacts of climate change and urbanisation in the Cholistan region.

Keywords: Cholistan desert, climate change, livelihood, livestock

Contact Address: Numan Arshad, University of Göttingen and Kassel, Department of Organic Agriculture, Khangura street rehmat colony, 39050 Narang mandi, Pakistan, e-mail: khanguranuman@gmail.com

Re-stocking vulnerable pastoral households with camels and goats helps increase their resilience

Pascale Waelti[1], Melina Griffin[1], Sara Imbach[2], Davis Ikiror[3]

[1]*Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*

[2]*Vétérinaires Sans Frontières (VSF) Suisse, Switzerland*

[3]*Vétérinaires Sans Frontières (VSF) Suisse, Office Nairobi, Kenya*

The integrated camel management (ICM) programme has been implemented since 2010 by VSF-Switzerland in the arid and semi-arid regions of Kenya, with the aim of improving food and nutrition security, health, income, and resilience of pastoral households. One domain of intervention is restocking vulnerable pastoral households with camels (and sometimes goats) and training in camel husbandry and milk hygiene. An evaluation was conducted by BFH-HAFL in 2021 to assess the impact of the project on pastoral households. A mix of methods was used, including documentation review, household surveys, and key informant interviews. A multi-stage sampling procedure was applied to select beneficiaries and control households with similar livelihood systems. 89 households were surveyed in 18 villages in Isiolo County. Results show that ICM project beneficiaries became more resilient to droughts and climate change than the control group, especially if they had been restocked with camels and goats for a long time. The ICM programme has also helped rise and stabilise the income, health, and food and nutrition security of poor pastoral households. This impact is primarily due to the increase and stabilisation of camel milk production and trade and is particularly important during the dry season and droughts. In addition to the distribution of camels, training in milking hygiene was seen by beneficiaries as crucial to the positive impact on their livelihoods, due to improved milk quality and reduced spoilage. The positive impact on food security was attributed to increased milk consumption at the household level and the ability to purchase more food through the sale of milk. Beneficiaries restocked with both camels and goats were more successful than those restocked only with camels, due to the complementary services provided by the two species. The gender analysis revealed that female beneficiaries were more involved in decision-making regarding camel management and camel milk use and income than female controls. In addition, the increased workload associated with camel husbandry seemed to affect men more than women and children. In conclusion, diversification into camel and goat keeping by restocking vulnerable households has proven to be an effective income diversification and climate change adaptation strategy.

Keywords: Camel value chain, climate change, food and nutrition security, Kenya, milk, pastoralism, resilience

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Contact Address: Pascale Waelti, Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), 3052 Zollikofebt, Switzerland, e-mail: pascale.waelti@bfh.ch

Impacts of the COVID-19 pandemic on livelihoods of pastoral communities in the Kenyan rangelands

Jennifer Gitau[1], Julie Ojango[2], Edwin Oyieng[2], Nicholas Ndiwa[2], Judy Gachora[3], Anne Muigai[4]

[1]*University of Hohenheim, Agricultural Sciences, Germany*
[2]*International Livestock Research Institute (ILRI), Kenya*
[3]*Ministry of Agriculture, Liveststock,Fisheries and Cooperatives, Kenya*
[4]*National Defense University, Academic Affairs and Research, Kenya*

The global COVID-19 pandemic declared in March 2020 resulted in an unprecedented economic slowdown with social disruptions across communities. In the arid and semi-arid lands (ASAL) of Kenya which comprise more than 60 % of the national land mass, the resultant restrictions on movement of people with closure of markets for different products greatly affected pastoral communities whose livelihoods depend on mobility of their livestock herds. A rapid assessment tool was used to determine the impacts of the restrictions among pastoral communities participating in a programme aimed at improving productivity of sheep and goats in Isiolo, Marsabit, and Turkana counties of Kenya. Additional information was obtained from key stakeholders involved in activities related to livestock production in each county. Households provided information on dynamics within their goat flocks and costs and availability of inputs and services during the national "lock-down". Likert scale statements each with three responses were used to collate information that was subsequently analysed using principal component analyses. The binary response variables were weighted to derive a variable measuring the overall effects of COVID-19 the livestock enterprises. A higher value of the derived scale variable represented a positive effect while a lower value represented negative effect of COVID-19 on the farmer's goat enterprise. Across the three counties, COVID-19 significantly ($p < 0.005$) affected the acquisition of breeding animals, availability of food for household use, availability of farm labour, and animal prices when marketed. Inputs and services supporting goat production were also difficult to access resulting in increased animal mortalities due to diseases. Communities in Isiolo and Marsabit that are located closer to the capital city Nairobi, and community members who had a higher level of education were more negatively affected by the pandemic than others. Countries need to optimally define restrictive measures to protect the livelihoods of pastoral communities whose survival depends on mobility rather than implementing nationwide movement restrictions.

Keywords: COVID-19, livelihoods, pastoral communities

Contact Address: Jennifer Gitau, University of Hohenheim, Agricultural Sciences, Schloss Hohenheim 1, 70599 Stuttgart, Germany, e-mail: jennifer.gitau7@gmail.com

Navigating uncertainties: In what directions are Fulani pastoralists going nowadays in Benin?

Georges Djohy, H. Stowe Agbéssi

University of Parakou, National School of Statistics, Planning and Demography (ENSPD), Benin

West African pastoralists are more than ever subject to climatic, socio-economic, political and security-related uncertainties that increase their vulnerability and marginalisation. Studies have shown that, when facing shocks and stresses, pastoralists – depending on their level of access to resources and markets – embrace at least three livelihood trajectories: "moving up'', i.e. maintaining their pastoral life and strengthening their pastoral economy by increasing their herds; "moving out'', i.e. maintaining a foothold in pastoralism while seeking complementary or alternative sources of livelihood to avoid poverty; and "moving away'', i.e. exiting pastoralism and relying fully on other sources of income. This study analysed how Fulani pastoralists in northern Benin negotiated options in a context of multidimensional uncertainty recently aggravated by the Covid-19 pandemic and Sahel-rooted terrorist insecurity. A mixed-methods approach was used to collect data from 419 Fulani (280 men and 139 women) aged 15 years and over in three districts in northern Benin, namely Tchaourou, Parakou and Kandi. Results revealed that diversification of livelihood activities is an important survival strategy among the Fulani pastoralists (58 %), with an average of two activities per multi-active person. While men are more involved in livestock (37.50 %), trade (24.64 %) and crop farming (21.43 %), women are more active in petty trade (42.45 %) and crafts (37.41 %). Hierarchical cluster analysis revealed three pastoralist clusters: Cluster 1 (40.81 %), composed essentially of women practising only one activity, either handicrafts or petty trade; Cluster 2 (34.84 %), made up of men who have livestock keeping as their main activity and crop farming or trade as a secondary activity; and Cluster 3 (24.34 %), made up of men who practise only one activity, either in trade or administrative or private-sector work. In sum, two major trends have emerged in pastoralism in northern Benin: exiting from traditional pastoralism (moving away, i.e. Clusters 1 and 3) and diversifying and seeking added value (moving out, i.e. Cluster 2). There were no cases of "moving up" identified. These findings show that pastoralism has changed a lot in Benin and that it is important to take this into account in current government policies.

Keywords: Livelihood diversification, livelihood trajectories, pastoralists

Development of novel Egyptian local broiler chicken lines: An Egyptian model for similar initiatives in low- and middle-income African countries under natural biodiversity and climate challenges

Mona M. Ghaly[1], Farid K. R. Stino[1], Omer S. Rashed[2], Mostafa K. Nassar[1]

[1]*Cairo University, Fac. of Agriculture, Animal Production Department, Egypt*
[2]*Ministry of Agriculture and Land Reclamation, Agricultural Research Center, Animal Production Research Institute, Egypt*

Climate change, globally and regionally in Africa, impacts the productivity and welfare of broiler (meat-type) chickens during the summer, especially when extreme heat waves occur in arid and subtropical regions. Adapted-local breeds may hold a plausible genetic solution for climate resilience. Therefore, Egyptian poultry breeders aimed at genetically improving the growth of climate-resilience-local chickens and developing new lines of broilers that are adapted to hot climate. At Cairo University, since 2003, we are practicing breeding schemes on naturally adapted local populations to generate local crossbred lines from the initial crosses between the two grandparents of commercial broiler female and male lines and two populations of adapted local chickens to local environmental conditions; White Baladi and Bandara. Afterward, the phenotypic selection was practiced for high growth at the marketing age of 6-week. Two crossbred lines were obtained, Cairo female line and Giza male line. The body weight of developed crossbreds was significantly around 2.4-fold heavier than those of the locals at week 6. In the Giza male line, we introduce naked-neck gene to enhance heat tolerance by crossing Naked-Neck breed with Giza chickens. Subsequently, Giza male chickens will be crossed with Cairo female chickens to produce a novel slow-growing Egyptian local broiler adapted to summer heat waves and inferior management conditions. Last year, we crossed them to produce the Cairo-Giza cross hybrid, for the first time in Egypt, named the Cairo-Mix broiler (n = 300). Although it is not as fast-growing as the international commercial strain, it performed much better than the local breed. Cairo-Mix reached 1.34 kg by 56 days of age compared to 600 g for the locals. The feed conversion ratio was 2.13. Cairo-Mix chicken has very low mortality (2 %) and a good dressing percentage (65 %). Despite its long growing period, it reached satisfactory economic efficiency. This improves animal welfare and contributes to maintaining the free-range or backyard poultry production systems and the competitiveness of the chicken industry in future business strategies under natural biodiversity and climate challenges.

Keywords: Animal welfare, food security, global warming, local Egyptian chicken

Contact Address: Mostafa K. Nassar, Cairo University, Fac. of Agriculture, Animal Production Department, 12613 Giza, Egypt, e-mail: mostafa.nassar@agr.cu.edu.eg

Farmers' perception of sheep production constraints in rural Egypt

Helmy Metawi, Eman El- Bassiouny

Animal Production Research Institute, Sheep and Goats Research, Egypt

This study was conducted on small ruminant production constraints in rural areas of the Nile Delta in Egypt during the period from January 2021 to April 2022. A survey questionnaire was developed and pre-tested to collect quantitative data from one hundred and eight randomly selected families and interviewed separately. The household was asked to identify the most important obstacles facing the production of small ruminants and arrange them according to priority. Microsoft Excel was used to analyse the data. Descriptive statistics such as percentages and frequencies were performed. To examine the profitability of small ruminant production, the internal rate of return (IRR) was measured for each respondent based on actual field records during the period of this study. The results showed that the average productivity of sheep flocks in the Delta region was estimated at 23.80 kg; while the IRR obtained from raising sheep (14.5 %) was not a good alternative to whether this money was invested in the bank at the currently available interest rate (16 %). The study concluded that small ruminant projects are not economically feasible and this is related to a number of factors, in which animal feeding challenges ranked first (95 %) among the problems faced by farmers in the Delta region. Disease control came second (62 %), followed by low animal productivity (43 %), high pre-weaning mortality rate (36 %).The expected changes in the IRR were estimated as a result of the possible deterioration of the reproductive and productive performance of sheep. A 10 % decrease in the number of weaned lambs per ewe would reduce the IRR by 3.8 %. Reducing the weaning weight of the lambs by 1 kg leads to a decrease in the IRR by 1.8 %. A 10 % worse change in feed costs would drop the IRR by 7 %. Therefore, national research work supported by an effective extension program to improve small ruminant production in rural Egypt must be implemented.

Keywords: Constraints, productivity, profitabilit, rural Egypt, sheep

Contact Address: Helmy Metawi, Animal Production Research Institute, Sheep and Goats Research, 5 Nadi Elsaid Str.Dokki, Giza, 16128 Dokki Cairo, Egypt, e-mail: hrmmetawi@hotmail.com

Climatic stressors induced molecular responses of crossbred dairy cows in tropical Savannah region

Mullakkalparambil Velayudhan Silpa[1], Kerstin Brügemann[1], Md Shahin Alam[2], Tong Yin[1], Chikamagalore Gopalakrishna Shashank[3], Chinnasamy Devaraj[3], Veerasamy Sejian[4], Raghavendra Bhatta[3], Eva Schlecht[2], Sven König[1]

[1]*Justus-Liebig University Giessen, Inst. of Animal Breeding and Genetics, Germany*
[2]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*
[3]*ICAR-National Institute of Animal Nutrition and Physiology (NIANP), India*
[4]*Rajiv Gandhi Institute of Veterinary Education and Research, India*

Climate change has a deleterious impact on livestock production system which adversely affects both the livelihoods of farmers as well as the supply chain of animal origin food. A study was conducted to assess the impact of climatic stressors (seasonal transition and temperature humidity index (THI)) on the molecular response of 40 lactating crossbred dairy cows reared by small-scale farmers in Bengaluru, India. The research period comprised the transitioning season of hot summer to wet monsoon, wherein the gene expression in bovine peripheral blood mononuclear cells (PBMCs) was assessed at two points, late summer (June) and early monsoon (July). Selective genes were considered; these were reported to be associated with (a) heat stress and adaptation: heat shock factor-1 (HSF1), heat shock protein 70 (HSP70) and HSP90; (b) production: growth hormone (GH), growth hormone receptor (GHR), insulin-like growth factor-1 (IGF-1) and leptin (LEP); and (c) inflammatory/immune response: interleukin 18 (IL18), interferon gamma (IFNγ), IFNβ and tumor necrosis factor alpha (TNFα). The mRNA isolated from the bovine PBMCs were subjected to quantitative Real Time PCR using Glyceraldehyde-3-phosphate dehydrogenase and Hypoxanthine phosphoribosyl transferase 1 as reference genes. Seasonal transition and/or higher THI significantly upregulated the relative PBMC mRNA expression of HSP70, IL18, IFNβ, IFNγ, TNFα, GH and IGF-1 genes during late summer as compared to early monsoon. The significant upregulation of the molecular chaperone HSP70 could indicate the activation of a "second window of protection" against cellular stress. Further, all of the selected inflammatory/immune response genes were significantly upregulated at higher THI and/or in late summer. The results revealed the significant influence of climatic stressors in activating both adaptation and immune response related transcripts in dairy cows. Thus, the study reveals the compromised immune system during exposure to climatic stressors in dairy cows. Further, the study points towards the fact that these targeted genes could serve as biomarkers for quantifying climatic stressors in dairy cattle in tropical Savannah regions.

Keywords: Adaptive responses, climatic challenges, dairy cattle, gene expressions, immunity

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Production parameters estimates of smallholder pig production systems in Uganda

Edwin Oyieng[1], Karen Marshall[1], Matthias Gauly[2]

[1]*International Livestock Research Institute (ILRI), Kenya*
[2]*Free University of Bozen - Bolzano, Faculty of Science and Technology, Italy*

The smallholder production system in Uganda significantly contributes to the increase in pig production and local pork consumption. In this paper, we present the estimates of production parameters for smallholder pig farmers in Uganda. Baseline household and longitudinal surveys were conducted from 191 pig keeping households in Hoima and Kamuli districts. The households were mainly male headed with an average household size of 6.0 ± 2.6. The farmers had either primary or secondary education as the highest level of education. The household land size was on average 2.3 ± 1.7 acres. The average herd size, sows and litter size was 3.78 ± 4.06, 1.48 ± 0.95 and 7.2 ± 2.3 respectively. Piglets comprised 11 %, weaners 22 %, growers 43 %, finishers 19 % and late finishers 5 % of the herd. The average age at first parity, parities per sow per year, farrowing interval and annual still birth rate was 11.3 ± 1.1 months, 1.4 ± 1.1, 261 days and 0.02 respectively. The piglets weaned per sow per year was 7.1. The annual mortality rates reduced from piglets to late finisher stage. 85 % of the animals exited the farms through sales while 70 % entered the farm through births. The annual overall offtake rate was 3.04 while the annual offtake rate from sale of pigs was 2.76. The overall annual intake rate was 1.34 while the annual intake rate from purchase of pigs was 1.31. 41 % of the pigs sold were weaners, 24 % growers, 22 % late finishers and 13 % finishers at an average price of USD.19.33, 38.53, 58.07 and 46.21 respectively. The annual health cost for curative treatment was higher than for preventative treatment across each animal type. Weaners had the highest cost for curative and preventative treatments. The most bought feed types were maize (70 %) and rice (28 %) bran which costed USD.0.10 and 0.75 per kg, respectively. Sow service was on average USD.3.09 ± 2.75. The cost of the piggery housing was on average USD.110.66 with an annual maintenance cost of USD.7.63. Other costs related to the pig farming (tethering, farm equipment, pig slaughtering) amounted to USD 3.85 per year. This information is important for evaluating the profitability and sustainability of the smallholder pig production system in Uganda.

Keywords: Pigs, production parameters, smallholder, Uganda

Knowledge systems

Knowledge systems and digitalisation

Online posters

The best of two worlds? Problems and new approaches of science communication with practitioners in sustainable agriculture

Ariane Goetz, Martina Padmanabhan

Passau University, Chair of Critical Development Studies, Germany

Science communication is essential for the implementation of agricultural and environmental sustainability goals in agriculture. The reference to practical knowledge, the capacities and needs of farmers and the local context are a prerequisite for providing practice-relevant knowledge and bringing sustainable agriculture into the mainstream. In reality, however, there are considerable problems of communication, relevance and legitimacy of science communication. On the one hand, perceptions of problems and solutions are often far apart between the farmer's view and the researcher's view. On the other hand, science itself is currently divided on what it takes to achieve sustainability goals in the sector. Furthermore, communication with practice is mostly neglected in the science system. Often it remains unclear whether, where and how science communication with practice takes place, and thus also to what extent what is communicated is useful in the respective context, and whether it is effective with respect to the goal level.

In a first step, this paper provides a systematic overview and categorisation of current problems of science communication with agricultural practice in view of knowledge exchange and sustainability. In a second step, the results of this synthesis effort serve as a basis for discussing current science communication attempts to overcome the mediation, relevance, and legitimacy problems through new content, formats, and processes. Several questions are at the centre of the investigation: what are predominant problems of science communication with practitioners? How are they addressed by means of current science-communicative innovations (in terms of content, format and process)? Which problems are being neglected? And to what extent can the innovations be expected to contribute to a better effectiveness of the exchange of experiences and the environmental and agricultural sustainability claim.

Keywords: Agricultural transformation, science communication, knowledge politics, knowledge systems

Contact Address: Ariane Goetz, Passau University, Chair of Critical Development Studies, Dr.-Hans-Kapfinger-Straße 14b, 94032 Passau, Germany, e-mail: ariane_goetz@yahoo.com

Roles and practices of agricultural extension agents in transforming the extension system in Ethiopia

Yemane Asmelash Gebremariam[1,4], Joost Dessein[1], Beneberu Assefa Wondimagegnhu[2,4], Mark Breusers[3], Lutgart Lenaerts[1], Enyew Adgo[4], Steven Van Passel[5], Amare Sewnet Minale[4], Amaury Frankl[6]

[1]Ghent University, Dept. of Agricultural Economics, Belgium

[2]Policy Studies Institute Ethiopia, Ethiopia

[3]KU Leuven, Inst. for Anthropological Research in Africa, Belgium

[4]Bahir Dar University, Ethiopia

[5]University of Antwerp, Dept. of Engineering Management, Belgium

[6]Ghent University, Dept. of Geography, Belgium

There are many ways to envision and approach rural innovation and extension processes. Knowledge and skills of extension agents on transferring technologies and innovation systems are essential for a successful practice. These skills enable extension agents to effectively support individuals and groups engaged in agriculture-related activities. A flexible delivery method is also necessary for a smooth extension system. Extension agents who promote various agricultural extension approaches assume they know what is best for farmers. However, information about the roles and practices of extension agents in the country (Ethiopia) is required, especially when considering technology transfer and innovation systems. These improve the performance of agricultural extension agents. The study aims to identify extension agents' roles and practices in transforming the extension system from the transfer of technology (ToT) to the agricultural innovation system (AIS) in northwest Ethiopia. A qualitative research approach was deployed to analyse 22 Key Informant Interviews (KIIs) and 23 focus group discussions (FGDs) with both men and women. The data were analysed using NVivo, version 12, for a thematic, deductive approach. The research shows that extension agents serve as facilitators, extension propagandists, fake reporters, model farmers selectors, persuaders, innovators, suppliers, go-betweens for researchers and farmers, trainers, technology disseminators, and resource linkers. Hence, extension agents must fully understand AIS techniques; ToT systems are still in use. As a result, it is essential to expand the institutional capacities of agricultural organisations that would enable the AIS to become more client-focused and responsive to the needs of smallholder farmers and extension agents.

Keywords: Extension agents, innovation system, transfer of technology

Contact Address: Yemane Asmelash Gebremariam, Ghent University, Dept. of Agricultural Economics, Coupure Links 653, 9000 Ghent, Belgium, e-mail: yemaneasmelash.gebremariam@ugent.be

Can digitalisation contribute to sustainable transformation of smallholder agriculture in Africa?

Evelyne Njuguna[1], Thomas Daum[1], Regina Birner[1], John Mburu[2]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*University of Nairobi, Dept. of Agricultural Economics, Kenya*

Agricultural development of smallholder farmers in Africa is held back by several challenges. These include lack of information and knowledge, inadequate access to agricultural inputs and services, and poor connectivity to production markets. High hopes are pinned on digitalisation to bring about much-needed change in African agriculture, but there is limited empirical evidence on the nature and impact of such digital tools on smallholder agriculture. We examine the landscape of digital agriculture in Kenya, an agricultural country and a leading centre for agricultural technology among low- and middle-income countries. Using a novel classification framework and a stocktaking approach, we analyse current technology trends to understand the extent to which these technologies are leveraging recent developments in sensing and analytics. This shows that the number of tools has tripled in ten years and there has been a shift from "simple" to "smart" digital tools that provide farmers with less generic and more tailored advice based on the data they input or data from sensors. Although the literature on the impact of these tools on smallholder agriculture is sparse, the potential impact pathways developed show great potential for further development of stronger value chains, increased market participation, improved food and nutrition security, higher incomes, increased environmental protection and climate resilience. To promote the contribution of digitalisation, we need to strengthen partnerships between private and public institutions to increase complementarity in e-extension and e-marketing, use publicly available satellite data that can give farmers a competitive advantage, develop legal frameworks for data management to promote trusted participation, and also advance a research agenda focused on the impact of these tools.

Keywords: Africa, agricultural transformation, classification framework, digital tools

Contact Address: Evelyne Njuguna, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), 70593 Stuttgart, Germany, e-mail: evelynenjuguna@gmail.com

Crop yield estimation using mobile pictures and deep learning in collaboration with thousands of smallholder coffee producers

Juan Camilo Rivera Palacio[1], Christian Bunn[2], Ryo Masahiro[1]

[1]*Leibniz-Centre for Agricultural Landscape Research (ZALF), Research Platform Data Analysis and Simulation, Germany*

[2]*The Alliance of Bioversity International and CIAT, Climate Action, Colombia*

The use of earth observation data, unmanned aerial vehicle imagery and manual counting for coffee crop monitoring are popular methods for predicting crop yield in Latin America. However, the coffee crop's environmental conditions, such as systems under shade, along with the time-consuming nature of the process, create a barrier to the extensive use of these methods at plot and larger scales. This study explored the use of mobile pictures of coffee trees for yield prediction at tree level in agroforestry systems for five coffee varieties in Colombia and Peru, in the form of citizen science. The object detection deep learning model, "You Only Look Once" YOLO v5, and manual counting were used together with extensive field monitoring data comprising information from 977 farmers, 2954 trees, and 10195 mobile pictures. The model was trained with two varieties of trees, Catimor Cogollo Morado and Catimor Cogollo Verde, in Peru. The training data consisted of ca. 35,000 labeled cherries. After model training, we deployed the model in Colombia with varieties variedad Colombia and supremo to test if the model can be useful in other regions. The results of yield prediction revealed an R-squared value of 63 %. The model achieves good performance with unseen data, and the model performance was as good as previous studies which employ more advanced but expensive techniques. Our study demonstrated that the method can generate yield predictions in seconds without the need for any expensive monitoring devices. Additionally, the use of mobile pictures can generate yield data for multiple zones where there is a lack of such data. This indicates the possibility of using mobile pictures to predict crop yield at the plot and even much larger scales for efficient planning and access to financial services. Future work should focus on the role of human users in the use of the machine vision system to further improve the accuracy of the results.

Keywords: Artificial intelligence, citizen science, coffee, deep learning, object detection

Contact Address: Juan Camilo Rivera Palacio, Leibniz-Centre for Agricultural Landscape Research (ZALF), Research Platform Data Analysis and Simulation, Müncheberg, Germany, e-mail: juancamilo.rivera@zalf.de

Farmers' perceptions on use of video as alternative tool for learning climate smart agriculture

Damilola Aladesuru, Christine Bosch, Regina Birner

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Agricultural extension plays a vital role for ensuring food security because agricultural extension provides knowledge, innovation and adaptation support to help farmers improve their production and manage climate change risks. However, several challenges faced by the agricultural extension systems in developing countries make it necessary to develop and use alternative, innovative approaches through which farmers can be advised about practices that can improve their resilience against climate change. This study presents the perceptions of farmers in Kenya on the use of videos as an agricultural extension tool for climate-smart agriculture, using the context of an agricultural development and research project that uses digital tools to reach women farmers with knowledge of climate-smart agricultural (CSA) practices in regions of Kenya, Uganda and India. Specific interest is in women farmers, given their high contribution to agriculture and higher vulnerability to climate change risks. The study used qualitative and quantitative methods of data collection such as focus group discussions, key informant interviews and participant observation. The collected data were analysed using deductive content analysis based on identification of themes, quantitative summary statistics and cross-tabulations. Gender was found to have significant relationship with farmers' level of implementation of CSA practices as 76 percent of women were using some CSA practice shown in the videos at the time of study, while most male farmers had tried but stopped the practices. Women expressed the influence of featured women rather than men farmers as motivating factor leading them to use these practices. Both men and women farmers regard videos as able to present graphically not only new practices but also those that had been learned from extension officers. Further findings suggest that higher decision-making power of men in the household contributes to factors that constrained some women's implementation of new practices. For future adaptation of videos, extension officers highlighted the need for a platform where farmers can interact with professionals like extension officers after watching the videos to clarify concerns. The study also identified some challenges to scaling of videos for agricultural extension, including technology requirements and willingness to invest in video technology.

Keywords: Agricultural extension, climate-smart agriculture, digitalisation, women farmers

Contact Address: Damilola Aladesuru, University of Bonn
current address: University of Bonn, Data Science in Agricultural Economics Group, Inst. of Food and Resource Economics, Bonn, Germany, e-mail: damilola.aladesuru@ilr.uni-bonn.de

ID 304

Research gaps for the horticultural sector in least developed countries: Monitoring urgencies and brokering research

Edouard Lehmann, Pieterjan De Bauw, Lilian Muriuki, Alice Jacques, Thomas Lopes, Morag Webb

COLEAD, Research & Innovation Brokerage, Belgium

The need to transform food systems is ever more pressing. Strategic research is a key component in this process, but it must be tailored to local contexts and should address the most pressing needs, particularly in the least developed country (LDC) context. To improve impact and research uptake, the research process needs to follow a set of guiding principles including stakeholder engagement, contextualisation, communication, the development of strategic partnerships, and capacity development. It is also crucial to direct more effort toward identifying existing technologies that have the potential to address priorities, but which may have not yet been adapted, implemented, or made affordable/accessible in LDCs. Current gaps between private sector needs, the dynamic policy landscape, and the (academic) research world remain significant, and an impediment for the transformation to more sustainable food systems. COLEAD is a not-for-profit private sector association consisting of a network of companies, professional organisations and experts committed to inclusive and sustainable agriculture. It established both a process and monitoring & evaluation system to continuously track research needs in the LDC horticultural sector, and actively promote and facilitate research uptake towards ensuring sustainable production, global trade, and market access.

In this presentation, the Research and Innovation Brokerage department of COLEAD will outline its current modus operandi and the open access monitoring & evaluation tools in place to address most pressing research gaps. We will demonstrate the crucial steps of (i) stakeholder engagement; (ii) creating international research linkages; (iii) identifying existing technologies; (iv) localising research; (v) meeting international standards and regulations; (vi) promoting policy dialogue (public, private, donor); (vii) and facilitating public-private engagement. We will outline the various monitoring tools developed and used by COLEAD including the AGRINFO system; producer/company surveys; the Sustainability Self-Assessment System (SAS); Market Analytics; and the monitoring of trade data on SPS non-compliances as well as our main findings and conclusions. Our aim is share information with researchers and donors on the priority research needs, and facilitate research linkages and partnerships in order to address these needs and support the transformation to sustainable horticulture and trade in the global South.

Keywords: Gap analysis, horticulture, knowledge management

Contact Address: Pieterjan De Bauw, COLEAD, Research & Innovation Brokerage, Avenue arnaud fraiteur 15/23 I B, 1050 Brussels, Belgium, e-mail: pieterjan.debauw@colead.link

Farmers' willingness to pay for improved vegetable extension service: The case in northwestern Ethiopia

Ermias Tesfaye Teferi[1], Tigist Damtew Worku[2],
Solomon Bizuayehu Wassie[2], Bernd Müller[3]

[1]*Bahir Dar University, College of Agriculture and Environmental Sciences, Ethiopia*
[2]*Bahir Dar University, Agricultural Economics, Ethiopia*
[3]*Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Germany*

Since 2020, TOMATO project has been carried out by Bahir Dar University in collaboration with Weihenstephan-Triesdof University of Applied Sciences (HSWT). Through research and education, the initiative seeks to spread advanced methods and technology for growing vegetables. This article looked into farmers' willingness to pay for enhanced vegetable extension services. As the current governmental extension service is mocked for huge inefficiencies, building a private, responsive, and demand-driven advisory service can play a vital role in addressing inefficiencies. Therefore, this study examined farmers' willingness to pay for enhanced vegetable extension services. The discrete choice experiments (DCE) used several choice cards that define the proposed extension service by varied attribute and attribute levels. The experiment divided the 393 sample houses into three groups, yielding 7074 observations. The mixed logit model's result revealed that farmers are more likely to pay for extension services that emphasise fruity vegetables over other sorts of vegetables such as root and leafy. Agronomic management skills were also more preferred over input-focused one and more hands-on, practical services over theoretical ones. Farmers are willing to pay 3 fold more money weekly extension visits than the amount they are willing for a monthly based service. Similarly, they are five times more willing to pay for fruity vegetables extension service than the amount they willingly pay for root vegetables. Farmers are ready to spend three times as much on weekly extension visits as they are on a monthly basis. In a similar vein, they are ready to spend five times as much for fruity vegetable extension services as they do for root vegetables. The results suggest that more field-based follow-up and monitoring should be included in private extension service models than should be done in offices.

Keywords: Choice experiment, extension services, willingness to pay

Contact Address: Ermias Tesfaye Teferi, Bahir Dar University, College of Agriculture and Environmental Sciences, Bahir Dar, Ethiopia, e-mail: ermiastesfaye61@gmail.com

A political ecology approach for the co-production of knowledge in living labs

Ryan Nehring

International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, United States

The concept of "co-production" has gained notoriety among academics and development professionals as an umbrella approach for collaborative research. Although there are numerous critiques on the ubiquity of the concept, it does provide a useful way to consider the role of plural knowledges within scientific processes. Existing definitions of co-production are vast and often contradictory. This paper proposes a political ecology framework to be applied to the concept of co-production of knowledge in applied research on low emissions food systems. Political ecology is an interdisciplinary field that focuses on the relations of power between nature and society. When applied to the co-production of knowledge, political ecology offers a framework to situate plural knowledge systems within the relations of production and within specific groups of (marginalised) peoples and their relationship to environmental change. This paper develops a framework to analyse how knowledge is co-produced between CGIAR researchers and local stakeholders in order to develop innovations for low emissions food systems. The analytical framework will be applied in two case studies of knowledge co-production: in Nandi County, Kenya and in the Department of Caquetá in Colombia. These are two of the four target countries where the CGIAR Research Initiative on Low-Emissions Food Systems is working with food systems stakeholders to collaboratively identify and develop innovations. The political ecology framework for the co-production of knowledge is being developed in conjunction with this initiative to understand whose knowledge has authority in the regions and how collaborative relationships can have a long-lasting impact for inclusive development of the food system. This paper outlines the framework and provides the rationale for qualitative methodologies to be deployed in each of the two sites for data collection. It offers a practical application of the concept of "co-production" that is both place-based and adaptable to food systems context.

Keywords: Co-production, epistemology, food systems, knowledge, living labs, political ecology

Contact Address: Ryan Nehring, International Food Policy Research Institute, Natural Resources and Resilience Strategies Unit, 1201 I street nw, 20005 Washington, United States, e-mail: r.nehring@cgiar.org

Farmers' perception of the effects of interactive training and on-farm testing of seedball technology for enhancing adoption: Case of Maradi region, Niger

Hycenth Tim Ndah[1], Andrea Knierim[1], Hannatou Moussa[2], Charles Ikenna Nwankwo[3], Ludger Herrmann[3]

[1]*University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany*

[2]*National Institute of Agricultural Research (INRAN), Niger*

[3]*University of Hohenheim, Soil Chemistry and Pedology, Germany*

Meeting global food needs in the 21st century, require a doubling of the present world food production by 2050.This challenge is of priority for Sub-Saharan Africa (SSA) where the level of food insecurity grew over the last two decades. Integrating sustainable Intensification (SI) practices into smallholder agriculture, is recognised as a crucial component of any strategy, toward meeting this challenge. One such practice,recently introduced in West African Sahel has been the "seedball" technology. As a technological innovation, it is an affordable "seed-pelleting" technique that combines indigenous local materials (e.g., sand, loam, water, and seeds) in a gravimetric ratio to enhance seedling establishment. Aimed at improving small-scale farmers' production of millet, a series of consecutive interactive training alongside experimental activities on seedball was conducted within the SMIL project (https://smil.k-state.edu/) in the Maradi (Niger).

As part of this project, this study aimed at evaluating Farmers' perception of the effects of this technology on i) yield returns, ii) labour cost, iii) financial cost, iv) labour burden for men vs women, and v) the number of training received versus expected – as a result of the training. The study made use of a standardised structured questionnaire (as part of a mobile app), to survey 489 farmers across 5 districts in Maradi.

Findings revealed that interactive training created space for general awareness and a broader understanding of the purpose and the functioning of the technology. Especially, a positive perception of the effect of technology by farmers is reflected in the acknowledgment of positive yield returns, reduced labour burden, lower financial cost, and readiness to recommend technology to peers. In addition, most farmers favoured 2–3 training sessions for proper understanding of the technology as opposed to the one-time training received – an expectation that varied across the 05 districts.

We conclude that levels of comprehension of technology applications differ across the different districts in Maradi, hence the need for more targeted training. For further promotion and scaling, farmers suggest the following considerations: producing and selling seedballs at cheaper rates, introducing a seedball production machine, and using available production material that can be easily acquired locally.

Keywords: Adoption, interactive training, Maradi-Niger, perception, seedball, sub-Saharan Africa

Contact Address: Hycenth Tim Ndah, University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Stuttgart, Germany, e-mail: h.ndah@uni-hohenheim.de

Residue fact sheets for energetic and material use of agricultural crop residues in Ethiopia

Fabian-Constantin Sittaro, Sophia Bothe, Jonas Hoffmann, Friederike Naegeli de Torres

German Biomass Research Center (DBFZ), Bioenergetic Systems, Germany

Agricultural crop residues such as straw, husks, and leaves provide a rich source of biomass for energy and material use. In Ethiopia, agriculture is one of the most important economic sectors and crop residues can play an important role in meeting the country's growing energy needs. However, there is a lack of comprehensive data and information on the spatial distribution as well as the energy and material potential of crop residues, which hinders their efficient use. To address this problem, we have prepared residue fact sheets for 15 of the most commonly grown crops in Oromia, the largest region in Ethiopia.

Each fact sheet contains a map showing the distribution of the crop production in metric tonnes per square kilometer, based on spatially disaggregated crop production data from the International Food Policy Research Institute (IFPRI). The data have been resampled to provide a visual representation of the availability of crop residues on a regional scale. In addition we included crop-to-residue factors, which are crucial for estimating the amount of residue available for use. The fact sheets further compile information and data on the main crop residues, including chemical parameters and energetic values such as dry mass, methane potential, and heat value and list the most feasible energetic and material use cases.

Our work provides a valuable tool for policymakers, researchers and development agents to better understand the potential of crop residues in Ethiopia. The fact sheets can support decision making on the development of sustainable bioenergy and biomaterials value chains, contributing to the country's socio-economic development and climate change mitigation efforts.

Keywords: Agricultural residues, crop fact sheets, crop production data, Ethiopia, use cases

Cultivating integrity: Addressing the impact of predatory publishing on agricultural research

José Luis Urrea-Benítez, Anny I. Yedra-Cubillos, Stefan Burkart

International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia

Predatory publishers (PP) pose a significant threat to the credibility and reliability of scientific research, i.e., by allowing the seep of pseudoscience into scholarly literature. It is critical to keep the highest standards in academic publishing to ensure that only quality science is published. There is not a clear pathway for determining if a publisher is predatory, because the lines are blurred. However, PP often use deceptive tactics to appear legitimate, such as creating fake impact factors and indexing services. Such tactics create a breeding ground for scholars and scientists, who are under pressure to advance in their careers, which is often based on the number of publications. However, this is driven by the greed of PP and the more they publish, the bigger their profit, creating a vicious circle. These practices have led to an increase in the number of low-quality or even misleading papers being published, with significant costs for the credibility of scientific research. PP do not only have serious impacts on the scientific community but also on environmental sustainability. Agricultural science is no stranger to this phenomenon with the aggravating circumstance of certain topics with special sensitivity, such as climate change, GMOs, or use of agricultural inputs. Since articles published by PP have not undergone rigorous review or do not comply with scientific standards, their results may mislead other researchers that validate them as references in their research. Furthermore, these results may be used by policymakers to make decisions, in the context of implementing agricultural practices, or for creating fake narratives among the public opinion. Agricultural science should lead a change in this stalemate: Authors, the organisations they belong to, and the funders of their research should be committed to prevail quality over quantity and protect the integrity of research and the reputation of the academic community by being vigilant in selecting reputable publishers. It is recommended to review a publisher's reputation, editorial policies, and peer-review process before submitting a manuscript. Likewise, it should be avoided to make hasty, pressure-based decisions on where to publish that could harm the credibility of research and the scientific community.

Keywords: Open access, predatory journals, publish or perish

Contact Address: José Luis Urrea-Benítez, International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Km 17 Recta Cali-Palmira, 763537 Palmira, Colombia, e-mail: j.l.urrea@cgiar.org

ID 221

Assessing mining disturbance for ecosystem services in Ouagadougou, Burkina Faso using Landsat data

Oussama Himmy, Thanh Thi Nguyen, Youness Boubou, Katharina Hemmler, Suman Kumar Sourav, Ellen Hoffmann, Andreas Buerkert

University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Germany

Quarries are a type of open pit mines, where construction materials, such as granite and clay, are extracted from the earth's surface, leading to a major disturbance of vegetation and degradation of ecosystem services. In Ouagadougou, the capital city of Burkina Faso, quarries are an employment generator, however, their expansion and uncontrolled extraction practices are reasons of serious concern. Detecting, quantifying, and monitoring the extent of quarries and their impact over time is challenging due to their often-small size and irregular shape. Using traditional processing methods of remote sensing data to track the dynamics of quarries is often very time-consuming and requires high computing resources. In this study, we apply a Google Earth Engine (GEE)-based technique for binary classification of quarries and non-quarries using Landsat 9 images of Ouagadougou. Due to varying scales and patterns of quarries, LandTrendr, a trajectory-based algorithm, was employed in the time series analysis of Landsat images (1985–2022) to map annual disturbance effects on vegetation and rehabilitation patterns. We hereby aimed at generating maps of quarries with an overall accuracy higher than 90 % in our analysis of 257 quarries covering an area of 38 km^2. The LandTrendr outputs allow us to identify the years and magnitude of vegetation disturbance by quarries, as well as to assess the recovery of vegetation in abandoned quarries. Ground truthing by field work and by analysis of historical aerial photographs will be conducted to validate the remote sensing results. The study shows the capability of integrating GEE, Landsat data, and the LandTrendr algorithm for the effective monitoring of the impacts of quarrying on land cover, biodiversity, and water resources in Ouagadougou and indicates implementations for regions with similar characteristics.

Keywords: Binary image analysis, land use change, time series analysis, vegetation degradation

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Contact Address: Oussama Himmy, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: oussama.himmy@student.uni-kassel.de

Digital ethnobiology: Exploring the digisphere in search of traditional and indigenous knowledge and practices

Emiel De Meyer[1], Melissa Ceuterick[2]

[1]*Ghent University, Dept. of Plants and Crops, Belgium*
[2]*Ghent University, Health and Demographic Research, Belgium*

Over the past few decades, the scope of ethnobiological research has expanded due to the influence of globalisation and urbanisation. Advancements in technology, telecommunications, the internet, and social media have facilitated the development and maintenance of ties within and between communities through multifaceted forms of digital communication. As a result, digital or virtual communities have emerged, providing platforms for sharing knowledge, perspectives, and ideas. In many rural areas, digital networks are now widespread and robust, with farming cooperatives, smallholder farmer networks, and trader networks using networking platforms and forums for communication and knowledge exchange. Similarly, both local and transnational digital social networks have emerged within and between diverse communities in urban settings, including migrant communities. These digital networks serve as platforms for sharing ethnobiological data and catalyze its adaptation to new environments. We emphasise the significance of these virtual digital social ties and the associated exchange of ethnobiological knowledge among and between ethnic groups. The latter has led to an expansion of the ethnobiological field of study into a digital or virtual environment. We propose the term "digital ethnobiology" to refer to the scientific study of the dynamic relationships between peoples, biota, and environments in a virtual or digital environment. Addressing the significance of digital ethnobiological knowledge exchange offers numerous opportunities for among others, research, development, conservation, capacity building, and communication. However, it also has far-reaching implications for the theoretical approach to ethnobiological research. We address and discuss opportunities, concerns, challenges, future perspectives, and raise some relevant questions regarding good research practices.

Keywords: Digital ethnobiology, digital networks, knowledge systems, migrant groups, urban ethnobotany

Contact Address: Emiel De Meyer, Ghent University, Dept. of Plants and Crops, Coupure Links 653, geb. A, 9000 Ghent, Belgium, e-mail: emiel.demeyer@ugent.be

Video tutorials for agricultural practices: Effective or useless?

Radip Tandukar

University of Hohenheim, Agricultural Economics, Germany

With 2 billion people involved in agriculture and only a handful of extensionists to support them, it is critical to explore emerging technologies of knowledge transfer to overcome the limitations of conventional extension systems. Agriculture video tutorials have emerged as a key tool to share, assist and motivate farmers to adopt improved cultivation practices but, a systematic exploration of its efficacy compared with conventional approaches is lacking. This study investigates the potential impact of agricultural video tutorials for rural farmers by reviewing literature published within the domain of ICT for agriculture extension. It also presents considerations to increase the adoption of video tutorials. We used literature databases and search engines to collect 48 initial papers, out of which 18 were primarily selected. The analysis puts forward the finding that video tutorials are equally effective if not more, to drive behaviour change against conventional methods. Combination of motion pictures and audio can deliver information effectively overcoming the barriers of illiteracy amongst farmers. Various internal factors like income level, age, etc. and, external factors such as language and timing of screening are said to influence the impact. Video tutorials have higher reachability and replicability. They should not be used as a substitute but complemented with human mediation or other forms of ICT to boost influence and drive behaviour change among rural farmers. The study opens door for further exploration on integrating video tutorials as a conventional approach of extension and intrigues research possibilities tackling the adoption and penetration to small holding farmers in the global south.

Keywords: Agricultural extension, digital agriculture, ICT, video tutorials

Contact Address: Radip Tandukar, University of Hohenheim, Agricultural Economics, Schwerzstrasse 3, 70599 Stuttgart, Germany, e-mail: radip34@gmail.com

GLEAM-X: An online application to support sustainable transformation of livestock systems towards lower emissions

Dominik Wisser, Giuseppe Tempio, Alessandra Falcucci

Food and Agriculture Organization of the United Nations, Italy

Livestock provide valuable nutritional benefits and supports livelihoods and the resilience of families and communities. At the same time, livestock systems are currently responsible for about 11 percent of all anthropogenic emissions and there are concerns about increasing emissions from the sector with the increased demand for animal products in the future (globally projected to be around 40 percent by 2050) so that ambitious action is needed to reduce emissions per unit of product (meat, milk, and eggs) and absolute emissions. At the same time, consumers are increasingly interested in environmental footprints related to animal products to make informed food choices.

Designing climate action and providing information for consumers requires sound, state-of-the-art, scientifically based data at very high level of detail and this need to easily accessible and should be able to demonstrate how different decisions in livestock production systems impact emissions. Building on existing tools, we have developed a prototype of GLEAM-X, a web application of the Global Livestock Assessment Model (GLEAM) that simulates emissions from different sources along the entire production chain and for different gases (CH_4, N_2O, and CO_2). Using projections for demand in animal products, the system simulates future emissions under a business-as-usual scenario and allows users to simulate the impact of specific interventions (improvement in feed quality, animal health, manure management) and productivity changes on total emission in the future. The system also generates UNFCCC compliant reports for emissions that can be used by countries to assess and report climate action for international commitments (such as the Paris agreement and the global methane pledge) and thereby support the transition of the sector towards lower emissions while minimising the environmental impacts.

Keywords: Climate change, livestock greenhouse gas emissions, methane, mitigation

Contact Address: Dominik Wisser, Food and Agriculture Organization of the United Nations, Rome, Italy, e-mail: dominik.wisser@fao.org

ID 823

GeoTree: A participatory digital tool for forest landscape restoration in the tropics

Anton Eitzinger[1], Christian Feil[1], Marius Ekue[2], Francis Oduor[3], Christopher Kettle[4]

[1]*International Center for Tropical Agriculture (CIAT), Climate Action, Colombia*

[2]*Bioversity International, Biodiversity for Food & Agriculture, Cameroon*

[3]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya*

[4]*Bioversity International, Multifunctional Landscapes, Italy*

Forest landscape restoration (FLR) in the tropics is often undertaken by smallholders and communities whose livelihoods rely on agriculture and forestry. While digital technologies can improve efficiency in FLR efforts, socio-technical barriers often impede the participation of these key actors in the restoration process. Main barriers are lack of technical infrastructure, access to digital tools and services, lack of ease of use for non-tech-savvy farmers, and lack of design targeted for low-literate and marginal groups. Moreover, precisely because of the transformative momentum of digitalisation, there is a risk for smallholders to enter the digital divide and power asymmetry gap. To address this challenge, the Alliance Bioversity International and the International Center for Tropical Agriculture have developed the GeoTree application, an extension of the GeoFarmer platform. GeoTree offers participatory functionalities, including interactive forms, polls, geospatial features and maps, and community-driven data collection, which can be integrated into community channels. The platform has been piloted in Kenya and Cameroon and tracks and monitors activities along the entire restoration chain, from seed collection to on-farm tree planting and monitoring of management activities and payouts to farmers. While other digital tools focus on monitoring tree planting for the purpose of carbon offsetting, GeoTree addresses the digital barriers facing smallholders and communities and enables them to participate fully in FLR efforts. GeoTree leverages blockchain technology to provide an integrated planting management process. The system allows gathering ground-level data with offline encryption and supporting low-internet environments and tracing the restoration process to provide transparency, facilitate real-time monitoring, evaluation, and verification, and support mobilisation of sponsors.

Keywords: GeoTree, restoration, tree

Technology acceptance model for adopting digital extension service: A comparative study of riceadvice use in Nigeria

Rico Amoussouhoui[1], Aminou Arouna[2], Marija Cerjak[3], Jan Banout[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic*
[2]*Africa Rice Center (AfricaRice), Côte d'Ivoire*
[3]*University of Zagreb, Dept. of Marketing in Agriculture, Croatia*

Digital extension technologies play an important role in agricultural development by providing adequate solutions to multiple challenges, such as climate change, farmers' inefficiency, and market information. The increasing growth of digital extension technologies represents an opportunity to supplement and enhance the traditional approach. Although many farmers are excited to use digital farming technologies, barriers such as a lack of technology devices (smartphones, internet, electricity, etc.), low e-literacy, and a lack of technology awareness make adoption challenging. This study examines rice farmers' behaviour in relation to a new adoption approach implying the adoption of "extension service" using technology. The study examines a treated group's behaviour in adopting the new approach as well as a control group's intention to adopt it. Primary data were collected on 1562 rice farmers, with 1202 treated (submitted to a paid extension service proposition) and 360 rice farmers in the control group (no extension service proposition). We employ an extended version of the technology acceptance model to examine farmers' behaviour in the two groups. In addition to the standard construct of the technology acceptance model, we added three more constructs to analyse farmers' perception of the proposed "payment method", "the price", and their "satisfaction". To analyse the collected data, we used partial least square equation modelling. The preliminary results from the field intervention show that 72.02 % of rice farmers accepted the proposed partnership. However, only 44.60 % have adopted and paid for the service. Further investigation will assist us in understanding the reasons for the rejection as well as the behaviour of farmers adopting a paid partnership. This study is expected to provide experimental evidence on farmer behaviour when adopting digital extension technology versus the intention to adopt an unexposed group. The findings will help policymakers and agribusiness investors design a more sustainable adoption strategy for digital extension technology, particularly for farmers in developing countries.

Keywords: Digital extension services, Nigeria, rice, technology, traditional extension approach

Contact Address: Rico Amoussouhoui, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Kamýcká 129, 16500 Prague, Czech Republic, e-mail: amoussouhoui@ftz.czu.cz

Agriculture and social media: A study of whatsapp use by livestock value chain actors in Nigeria

Linda Isuyi, Thomas Daum, Regina Birner

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Agricultural development plays a key role in achieving the SDGs in sub-Saharan Africa, but farmers and other value chain actors often struggle with missing and/or missing information and missing market linkages in rural value chains. Social media – WhatsApp in particular – can enable cheaper and better ways of disseminating information and new ways of integrating stakeholders into agricultural value chains. The study has two main goals. First, based on 196 interviews with actors in the dairy, pig and broiler value chains, we examine the use of social media platforms by actors in the livestock value chain in relation to other smart technologies. Second, we analyse the potential of WhatsApp to overcome some information and marketing bottlenecks in the abovementioned value chain. To do this, we analysed unique data from seven WhatsApp groups created by actors in the livestock value chain in Oyo State, Nigeria using content analytics. The results show that social media is already being used in agricultural value chains, but the usage rate is relatively low compared to other smart technologies due to a lack of courage to post online and a lack of understanding of how the platform works. Findings also showed that WhatsApp groups provided a safe space to show support and solidarity, connect, discuss, learn and share knowledge, information and experiences about farm animals with each other and with experts. However, there are concerns about the credibility, reliability and applicability of the information shared on this platform. The study concludes that social media platforms can play an important role in overcoming information asymmetries and missing market linkage pitfalls among others but have not yet been fully integrated into public agriculture extension. It is therefore imperative to prioritise social media platforms like WhatsApp in agriculture, especially in livestock value chains, by including them in the public extension portfolio, while considering the barriers to social media usage.

Keywords: Agriculture, livestock value chains, Nigeria, social media, WhatsApp

Contact Address: Linda Isuyi, University of Hohenheim, Social and Institutional Change in Agricultural Development, Wollgrasweg 43, 1.25, 70599 Stuttgart, Germany, e-mail: isuyi86@gmail.com

Factors affecting the acceptance of social networks as an educational resource by farmers: A study of farmers in southern Iran

Khadijeh Soleimani[1], Bahman Khosravipour[1], Masoud Yazdanpanah[1], Katharina Löhr[2], Stefan Sieber[2]

[1]*Agricultural Sciences and Natural Resources University of Khuzestan, Dept. of Agricultural Extension and Education, Iran*

[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Global changes caused by climate change and its destructive effects on the agricultural sector, such as water scarcity, reduction of crop yields, and threats to food security, have doubled the importance of increasing the adaptability of farmers. Farmers' access to up-to-date information and appropriate training is necessary and essential to deal with the phenomenon of climate change, which is limited in most developing countries due to the lack of resources, manpower, and appropriate infrastructure. The tremendous progress and high capabilities of information and communication technologies have led to the use of these technologies, including online social networks, as an important tool and source for educating, training, and informing farmers regarding climate change. If the farmers accept these social networks and use them, they can increase their ability to adapt and cope with climate change and be considered a useful solution .

Therefore, knowing the views and tendencies of farmers in using these social networks is the first step for proper policy-making in this direction. This research aims to investigate farmers' willingness in southwestern Iran to use social networks as a resource and educational tool to adapt to climate change. To achieve this goal, the technology acceptance model was used in a cross-sectional survey of a sample of 377 farmers. The structural equation model results showed that the perception of usefulness, ease, and attitude variables can explain 24 % of farmers' intentions. Based on the results of this research, suitable implication policies were presented to increase the use of these networks among the farmers of southwest Iran.

Keywords: Climate change, social networks, farmers

Contact Address: Khadijeh Soleimani, Agricultural Sciences and Natural Resources University of Khuzestan, Dept. of Agricultural Extension and Education, Ahwaz, Iran, e-mail: khadijeh.soleimani@gmail.com

Digitalisation of agricultural knowledge providers: Case study of Fars agriculture organisation in Iran

Seyedeh Bahar Homayoon[1], Masoud Yazdanpanah[2], Saeed Mohammadzadeh[1], Tahereh Zobeidi[3], Alexa Lamm[4]

[1]Agricultural Sciences and Natural Resources University of Khuzestan, Dept. of Agricultural Extension and Education, Iran

[2]University of Florida, Dept. of Agricultural Education and Communication, United States

[3]International Institute for Applied Systems Analysis, Cooperation and Transformative Group, Austria

[4]University of Georgia, ALEC, United States

Digitalisation makes significant changes in the structure, operation, and management of agriculture, among these changes, we can mention the transformation of organisational identity into digital identity. The changes made in the organisational identity are analysed based on four components: the speed of change, the nature of change, the source or motivation of change, and the context of changes among knowledge providers who are the specialists and experts of the organisation. The research method of this paper was qualitative and in the form of a case study. The studied case was the Agricultural Organisation of Fars Province, which is one of the top provinces using digital agriculture and, is important in Iran's agricultural production. This organisation has nine managers, and semi-structured interviews were conducted with 7 managers (It includes the coordination management of agricultural extension, water and soil, fisheries and aquatics, processing and food industries, and vice president of plant production improvement (which includes management of plant conservation, horticulture, and mechanised agricultural technologies). Surveys show that there are different perceptions of digitalisation among these knowledge providers, but they all agreed that in terms of speed of changes; digitalisation in this organisation started at a slow speed and has intensified over time and in the face of the coronavirus. In such a way that it can be said that almost all intra-organisational and inter-organisational matters are being done automatically (such as administrative correspondence platforms and virtual training). In terms of the nature of changes; these changes have been made with a long time horizon and the organisation is gradually and continuously changing. In terms of source and motivation; in some cases, the origin of these changes has been from the organisation itself (such as the panjareh; the digital system for organising food industry license applicants), in some cases, policymakers have ordered it to organisations (such as the zoning system). In terms of the context of changes; the Fars Agricultural Organisation is regarded as one of the leading organisations in the use of innovations and technologies. Therefore, the integration and acceptance of new and old methods of this organisation will be done well.

Contact Address: Masoud Yazdanpanah, University of Florida, Dept. of Agricultural Education and Communication, Gainesville, United States, e-mail: myazdanpanah@ufl.edu

Analysis of dairy farmer's willingness to pay for targeted extension and advisory services in Kenya

Julius Githinji[1], Gabriel Mwenjeri[2], James Rao[1]

[1]*International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods Program, Kenya*
[2]*Kenyatta University, Agribusiness Management and Trade, Kenya*

The dairy subsector plays a crucial role in the Kenyan economy, contributing to employment, food security, and agricultural productivity through manure provision. With approximately two million Kenyans relying on the dairy industry for their livelihoods, the sector has experienced consistent growth, driven by increased demand for value-added products, commercialisation, and adoption of zero-grazing practices. The growing domestic population and in the region coupled with the increasing middle-income class offers an even more promising future for the dairy industry in Kenya. However, despite this growth, dairy farmers often struggle to achieve profitability, facing challenges such as low milk productivity and high production costs. To enhance productivity, the adoption of new technologies and management practices is essential. Extension and advisory services are crucial in facilitating technology adoption among smallholder dairy farmers, empowered and well-informed farmers embrace innovation. Traditionally, the government has provided extension services, but the system has faced challenges, including an unsustainable ratio of government personnel to farmers, leading to criticism of its effectiveness and insufficiency. In response to these shortcomings, private extension and advisory services have emerged in the dairy sector, offering targeted and responsive support to farmers.

This study aims to estimate dairy farmers' willingness to pay for targeted private extension and advisory services in Nandi County using a discrete choice experiment, Kenya. The specific objectives are (1) to determine the socioeconomic and institutional factors of dairy farmers in Nandi County, (2) to establish the highest price farmers are willing to pay for targeted extension and advisory services, and (3) to identify the factors influencing farmers' willingness to pay. Employing a quasi-experimental design, the study compares the differences in willingness to pay between participants and non-participants of targeted extension services. A purposive sampling approach will be used to select pre-existing groups, and equal sample sizes will be allocated to participants and non-participants through random selection. Primary data will be collected from Lessos Dairy in Nandi County, with approximately 240 respondents. Descriptive analysis, discrete choice analysis, and a probit model will be employed to analyze the objectives. The study's findings will provide valuable insights for policymakers considering the use of dairy farmer assistants to deliver targeted extension and advisory services.

Keywords: Dairy subsector, extension and advisory services, willingness to pay

Contact Address: Julius Githinji, International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods Program, 30709-00100, 00100 Nairobi, Kenya, e-mail: J.Githinji@cgiar.org

ID 938

Competing pathways for equitable food systems transformation: Trade-offs and synergies

Phoebe Koundouri[1], Konstantinos Dellis[1], George Halkos[2], Kendrick Hardaway[3], Athanasios Yannacopoulos[1], George Papagiannis[1], Alexandra Ioannou[4], Chrysi Laspidou[4]

[1]*Athens University of Economics and Business, Dept. of International & European Economic Studies, Greece*
[2]*University of Thessaly, Dept. of Economics, Greece*
[3]*Purdue University, United States*
[4]*University of Thessaly, Civil Engineering Department, Greece*

Food security remains one of the main challenges within the UN 2030 agenda and global imbalances have been exacerbated by the COVID-19 pandemic and the recent energy crisis. Ensuring the functionality equitable food systems which leave no one behind whilst abiding to the climate targets set by the EU "Fit for 55" package and fulfiling national commitments enshrined in the EU Climate Law and the Greek Climate Law poses a pivotal policy and societal challenge for Greece in the coming years. Using an interdisciplinary approach to measure ecosystem services is instrumental in the calibration of shared socioeconomic pathways (SSPs) as their role in shaping natural capital directly affects land productivity and food produce both in terms of quantity as well as quality.

Having said that, we assess implications for food security considering the effect of improved ecosystem services on the quantity and quality of food production and the demand-side effect of a dietary shift to healthier standards in Greece. In doing so, we develop three scenarios, namely (i) business-as-usual until 2050, (ii) enhancement of ecosystem services and (iii) shift towards a Mediterranean diet. In addition, we evaluate the synergies and trade-offs among scenarios (ii) and (iii). For each scenario we model alternative specifications regarding population projections, caloric intake and crop productivity. We applied the FABLE calculator (Food, Agriculture, Biodiversity, Land use and Energy) to assess the evolution of the Greek food and land-use system from 2000 to 2050, as well as the impacts of these scenarios on GHG emissions, biodiversity targets and water footprints

Keywords: Ecosystem services, emissions, FABLE, food security

Contact Address: Konstantinos Dellis, ATHENA RC, SDU, Kosma Melodou, 11471 Athens, Greece, e-mail: kdellis@aueb.gr

Effect of information on farmers' preferences for disaster risk reduction measures: Evidence from a discrete choice experiment in western Uganda

Rodgers Mutyebere[1], Iris Vanermen[2], Clovis Kabaseke[1], Liesbet Vranken[2]

[1]*Mountains of the Moon University, Uganda*
[2]*KU Leuven, Dept. of Earth and Environmental Sciences, Belgium*

Disaster risks associated with landslides and floods severely affect farmers causing mortality, morbidity, and destruction of farms and farmlands thereby devastating livelihoods. By degrading fragile ecosystems on the steep slopes of high mountains through local farming practices, farmers also contribute to increased exposure to disasters, thus, they need to lead the implantation of disaster risk reduction (DRR) measures. However, it is not known what characteristics (attributes) of tree planting and/or diversion channels do farmers prefer to apply these DRR measures on their land, and how the information provided might alter such preferences. A discrete choice experiment (DCE) involving 319 households in western Uganda, a region prone to landslides and floods was conducted to investigate farmers' preferences. A between-subject design was used to provide information on the DRR measure in a video to investigate how information altered farmers' preferences. Initial analysis using a generalised multinomial logit model reveals a general preference for DRR measures with higher erosion risk reduction. Moreover, a moderate effect of information on preferences for more risk-reducing levels of attributes of tree planting was found, while the information effect on preferences for diversion channels was limited. Based on plot characteristics, in both tree planting and diversion channels, the information treatment effect was larger on larger plots, plots on steep slopes, plots at risk of landslides or floods, and plots that already have some DRR measures. Findings from this study provide us with key policy lessons in that government and other relevant bodies should provide more information on tree planting ex-ante to shape the farmers' preferences before embarking on breeding and supplying tree seedlings. This would reduce the problem of just dumping the seedlings to farmers with fewer (without) preferred attributes which might explain poor adoption behaviour for these measures.

Keywords: Disaster risks, discrete choice experiment, generalised multinomial logit, landslides and floods, preferences

Contact Address: Rodgers Mutyebere, Mountains of the Moon University, 837 Fort portal, Uganda, e-mail: mutyrodgers@gmail.com

Designing a framework for transferring climate information to non-experts (based on narrative communication and storytelling)

Davoud Rouzaneh[1], Masoud Yazdanpanah[1], Stefan Sieber[2,3], Katharina Löhr[3,2]

[1]*Agricultural Science and Natural Resources University of Khuzestan, Dept. of Agricultural Extension and Education, Iran*

[2]*Humboldt-Universität zu Berlin, Thaer-Institute, Germany*

[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Despite the scientific consensus about climate change and its devastating effects on Earth, public perception has resisted some of the most important scientific indications of climate change. The skepticism and indifference of the target communities create significant barriers to the effectiveness of policies, which has made it necessary to reexamine strategies for communicating science to the public audience. There are two types of communication including scientific-logical communication and narrative communication in literature, which are most used in the design of scientific information transmission frameworks based on scientific-logical communication. In recent years, researchers have paid attention to and studied narrative communication and storytelling as an effective form of scientific communication. By organising information in a way that is more understandable for human cognition, narratives help people to better understanding information and communicate with them. Research has shown that narratives are easier for non-experts to understand and audience find them more engaging than logical-scientific communications. Stories and narratives are a simple way for people to understand and understand information, which improves the acquisition and maintenance of information and encourages people to change their beliefs, attitudes, and behaviours. In the transfer of science to non-specialist audience, stories, and narratives are not only more appropriate but also more effective than scientific reports, which can increase understanding, interest, and interaction. Researchers believe that logical-scientific and narrative communication are not only opposite forms of communication, but as two distinct cognitive paths of understanding and recognition, they have the potential to combine to achieve defined goals, especially in the field of awareness-raising in relation to climate change. Scientific professionals can help people better understanding, accept, and discuss climate change information by combining recent findings with narrative science. This study tries to help design a climate information transfer framework for non-expert users in areas with poor educational infrastructure by reviewing the systematic research literature using the content analysis method.

Keywords: Climate change, information transfer, narrative communication

Food chains, food processing and consumers

Agrifood markets and value chains

Online posters

Impact of agroecological practices on farm performance in Botswana

Gideon Danso-Abbeam[1], Obakeng Tevin Selelo[2], Abiodun A. Ogundeji[1]

[1]*University of the Free State, DiMTEC, South Africa*
[2]*University of the Free State, Dept. of Agricultural Economics, South Africa*

Although agroecological techniques can help farmers establish sustainable agri-food systems, adoption of these practices is low, and evidence of their impact on farm performance is inadequate. Using data from 308 vegetable farmers at the farm level, this study assesses the adoption of agroecological practices and their effect on farm performance across four administrative districts of Botswana. The multivariate probit (MVP) model was used to understand the complementarity and/or substitutability of the key agroecological practices under consideration – mulching, cover cropping, afforestation, and minimum tillage, as well as their determinants. In addition, the direct-two stage least square (direct^{-2}sls) within the framework of instrumental variable treatment effect regression (ivtreatreg) was used to get rid of any self-selection bias that might be present due to observed and unobserved characteristics. The findings revealed that cover cropping and minimum tillage, cover cropping and mulching, as well as minimum tillage and afforestation, were used as complementary agroecological practices by vegetable farmers in the study area. However, afforestation and mulching, as well as minimum tillage and mulching, were used as substitutes. Farmers' decisions to practice these agroecological practices were influenced by a variety of socioeconomic, institutional, and farm-specific factors. Furthermore, the adoption of agroecological practices resulted in a significant increase in farmers' net revenue and yield (indicators of farm performance), and farmers who did not adopt any of the practices would have been better off if they had. Thus, adopting at least one of the agroecological practices increased the adopters' yield and net farm revenue by 29.8 % and 15.3 %, respectively, over what they would have obtained if they did not adopt. If non-adopters had adopted, their yield and net farm revenue would have increased by 31.6 % and 14.7 %, respectively. These findings have significant implications for stakeholders and will boost the campaign for the adoption of agroecological practices to improve farm performance and, consequently, farmers' welfare.

Keywords: Agroecology, Botswana, farm performance

Contact Address: Gideon Danso-Abbeam, University of the Free State, DiMTEC, Bloemfontein, South Africa, e-mail: dansoabbeam@uds.edu.gh

ID 266

Missing middle in agri-food transitions: The case of safe food supplying in Vietnam

Quoc Nguyen-Minh[1], Peter Oosterveer[1], Inge Brouwer[2], Ricardo Hernandez[3], Maja A. Slingerland[4]

[1]*Wageningen University and Research, Environmental Policy Group, The Netherlands*
[2]*Wageningen University and Research, Human Nutrition & Health, The Netherlands*
[3]*The Alliance of Bioversity International and CIAT, Vietnam*
[4]*Wageningen University and Research, Plant Production Systems, The Netherlands*

In agri-food systems, the Missing Middle can be understood as the disconnect between food production, distribution, and consumption, or between global agendas and local practices that hinder the progress towards achieving sustainability goals. This is manifest in many low and middle-income countries (LMICs) when the national policies of promoting food safety and modernisation can have potential misalignments with local implementation practices. The study explored the case of fresh vegetables and pork in Vietnam to illustrate the concept. The two commodity chains have essential roles in ensuring nutritional security and smallholder income, but both are grappling with persistent food safety issues. We adopted the social practice theory (SPT) and transition theory to zoom in and zoom out on the dynamics within different components of food systems and the interactions between those dynamics. The research is based on a scoping review of relevant documents and semi-structured interviews with agri-food actors along the supply chains. The results show how both supply chains are transitioning in seemingly different pathways to achieve the shared goal of improving food safety. For vegetables, small-scale producers remain the dominant actors, but their practices are shifting towards using more biopesticides and traditional eco-friendly approaches for crop protection and soil cultivation. Meanwhile, pork smallholders are upscaling their facilities and practices to enhance biosecurity, under strong competitive pressures from the rapidly growing large-scale and modern pork production. Hence, the two supply chains are struggling with different challenges, from labour shortage and the reduction of farmland for vegetables to high input prices, smallholder inclusiveness, and growing threats of disease outbreaks for pork. But we identified a shared 'Missing Middle' in both cases: the fragmentation within food supply networks, leading to difficulties to upscale safe and sustainable solutions and the erosion of consumer trust. This requires a more system-based approach to bridge the production-consumption disconnect in two cases, along with specific interventions to address different lock-ins and promote good practices along each supply chain.

Keywords: Agri-food transitions, food safety, food systems, missing middle, pork, vegetables

Contact Address: Quoc Nguyen-Minh, Wageningen University and Research, Environmental Policy Group, Postbus 8130, 6700 EW Wageningen, The Netherlands, e-mail: quoc.nguyen@wur.nl

Innovation scaling for equitable food systems transformation: Introducing an innovation bundle profiling tool to enhance scalability

Mirja Michalscheck[1], Muluken Elias Adamseged[2], Federico Ceballos-Sierra[3], Minh Thai[4], Petra Schmitter[4]

[1]International Water Management Institute, West Africa, Ghana
[2]International Water Management Institute (IWMI), Ethiopia
[3]The Alliance of Bioversity International and CIAT, Honduras
[4]International Water Management Institute (IWMI), Sustainable and Resilient Food Production Systems, Myanmar

While growth and innovations in the food sector have improved food security and livelihoods, food systems have strained natural resources and gains made were not necessarily equal amongst actors and farmers. The CGIAR Rethinking Food Markets Initiative aims to provide evidence on what types of bundled innovations, incentive structures and policies are most effective for creating more equitable sharing of income and employment opportunities, while reducing the food sector's environmental footprint. Scoping studies on food system innovations were conducted in seven countries (Ethiopia, Nigeria, Uganda, Bangladesh, Uzbekistan, Honduras and Guatemala) and combined with participatory workshops to co-design innovation bundles and interventions. This led to the development of an innovation bundle profiling tool which allows research teams to capture information on bundle components and characteristics, the bundling process, and to identify potential scaling pathways for enhancing impact. The tool was piloted in Honduras for an innovative commercialisation scheme to increase coffee quality and prices. The results provided a detailed overview of required actor relationships and resources for bundle testing and scaling; a market-led scaling strategy for the bundle, in which research for development plays a partnering role, supporting scaling actors with evidence on impacts. As part of adaptive management and process tracing, the profile entries shall be revised regularly to reflect novel insights and adjusted strategies. The profiling tool is applicable to any innovation bundle aimed at transforming food systems. The openly accessible tool is modular and user friendly. It is useful for researchers who are in the stage of developing or refining an innovation bundle as well as those who want to prepare for or reflect on their scaling success or failure. The profiling tool serves to enhance innovation bundle scalability, constituting an important catalyst for food systems transformation.

Keywords: CGIAR, co-design, coffee, Honduras, market-led scaling, process tracing, R4D, value chains

Contact Address: Mirja Michalscheck, International Water Management Institute, West Africa, PMB ct 112 Cantonments, Accra, Ghana, e-mail: m.michalscheck@cgiar.org

ID 782

The contingent interplay between resources, entrepreneurship, and agribusiness performance among small-scale agri-food actors

AYOBAMI ADETOYINBO[1], RHETT HARRISON[2], DAGMAR MITHÖFER[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci. - Agricultural Economics, Germany*
[2]*World Agroforestry, Zambia*

Strategic entrepreneurship is essential for business continuity, economic development, and poverty alleviation. Yet, smallholders such as farmers and traders in sub-Saharan Africa (SSA) display low levels of entrepreneurship and performance because they participate in agri-food segments with unstable business environments and inadequate resources. With theoretical and empirical perspectives on entrepreneurial behaviour and success being fragmented and inconsistent and empirical studies about entrepreneurship among small-scale agri-food actors notably scarce in SSA, there is a dearth of knowledge regarding how resources and entrepreneurship contribute to smallholders' business performance in different agribusiness situations. This study analyses the influence of entrepreneurship on the resource-based performance of rural farmers and traders in unstable business situations. We propose an innovative conceptual framework based on resource orchestration, entrepreneurial orientation (EO), and contingency theory. Multi-tier data obtained from 708 farming households and 639 fruit and vegetable traders in Zambia were analysed using structural equation models comprising mediation-moderation analysis. The results show that financial, physical, and social resources are positively related to farmers' and traders' EO, which in turn, mediates the effects of their resource portfolios on business performance. Findings from the moderation analyses, however, point to a mismatch in farmers' and traders' entrepreneurial behaviour and success in different business environments. As farmers' entrepreneurial success (i.e. EO-performance link) is moderated by contingency factors such as power asymmetry, competition, and tighter supplier-buyer relations, traders' entrepreneurial behaviour (i.e. resource-EO link) is moderated by business environments, such as trust, competition, and tighter supplier-buyer relations. The study's originality is found in the proposed conceptual framework, as well as its ground-breaking multi-tier empirical insight on how small-scale farmers and traders pool their resources to develop entrepreneurial capability, which they, in turn, use to maximise business performance in ambiguous business conditions. This study raises and discusses several theoretical, practical, and policy implications.

Keywords: Africa, agri-food actors, business performance, contingency theory, entrepreneurial orientation, resource orchestration theory

Contact Address: Ayobami Adetoyinbo, Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sciences - Agricultural Economics, Invalidenstr. 42, 10115 Berlin, Germany, e-mail: ayobami.adetoyinbo@hu-berlin.de

Analysis of the specialty cocoa value chain in Huila, Colombia

HERIZO MICHA FOURNIER[1], CÉSAR GARCÍA MORALES[2], INGRID FROMM[1]

[1]*Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*
[2]*Swisscontact Colombia, Expertise of specialty cocoa value chains, Colombia*

Colombia is a country with a high potential to produce specialty cocoa, but with low export volumes compared to regular cocoa. To enhance the potential of cocoa exports, the Cacao Más Sostenible projects aim at supporting cocoa farmers in Huila, the 5th largest exporter of fine flavour cocoa worldwide. The goal of this study is to analyse trends in specialty cocoa in the European and Swiss markets and the upstream potential of the cocoa value chain in Huila: nurseries, cocoa farmers, and producer associations. The methods used were literature research and quantitative and qualitative research, including stakeholder interviews and farmer surveys. European markets, especially the Swiss market, are showing great interest in the trade of sustainable specialty cocoa. Organic and Fairtrade certifications are important for targeting this specific niche market. Results indicate that nurseries have good production capacities but gaps in traceability due to a lack of formality. Good agricultural practices (GAP) could be adopted to overcome it. Most cocoa farmers do not fill all GAP. Smaller farms have more sustainable practices than larger ones. GAPs identified are the use of organic fertilizers and mechanical weeding whereas practices which still need to be improved are the use of chemical fertilizers, fungicides, and insecticides. The assessment of sustainable practices at the farm level indicates that there are weaknesses which need to be improved. As for the producer associations, no sustainable environmental practices could be identified, only social sustainability practices such as gender equity that is mostly respected through the integration of women on the boards of directors. In terms of integration into the European and Swiss markets, there are still gaps in terms of the necessary formalities to follow food safety, traceability, and hygiene protocols. It is important to highlight that there are common problems in the farmer and association segments: the ageing of cocoa farmers and the low number of young people willing to continue farming, climate change is another factor affecting production. There is a need to anticipate the repercussions by developing varieties adapted to climate change, pests and with specialty cocoa organoleptic profiles.

Keywords: Colombia, good agricultural practices, specialty cocoa, sustainability, value chain

Contact Address: Herizo Micha Fournier, Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), 85 länggasse, 3052 Zollikofen, Switzerland, e-mail: micha.fournier@bfh.ch

Maize farmers' willingness to pay for agricultural insurance in the Plateau region of Togo

Yao Marius Kpani, Mikémina Pilo

University of Kara, Lab. of Economics and Management Sciences, Togo

Maize producers in Togo experience significant losses due to unpredictable rainfall, floods, pest attacks, and technical failures, leading to increased vulnerability and reluctance to invest in production-enhancing technologies. Limited access to financing further exacerbates food insecurity and accelerates income reduction. Recent research support that agricultural insurance can help to withstand these adverse effects. However, the financing of the implementation of these risks' management mechanisms still challenging. Thus, in order to trigger the establishment of agricultural insurance, this study investigates the perception of maize producers in the Plateau region regarding agricultural insurance, assess their willingness to pay (WTP) for such services, and identify factors influencing their WTP. Data collected from 385 maize producers were analysed using Heckman's two-stage selection model. The majority of producers were male and viewed agricultural insurance positively. 80 % of respondents expressed a relatively high willingness to subscribe, with an average WTP of 9155 FCFA ($15.25). Factors influencing their WTP include membership in a farmers' organisation, access to credit, information about agricultural insurance, and perception of insurance. Demographic and socioeconomic factors, such as age, education level, use of mineral fertiliser, income, and other income sources, further explain the amounts they are willing to pay for such insurance services.

Despite the strong desire of producers to adhere to the agricultural insurance project, the development of agricultural insurance must be coupled with actions to make resistant varieties available, to make production inputs (fertilisers, seeds, etc.) available in a timely manner, to organise producers into co-operatives and to strengthen their technical supervision, as well as to adopt an inclusive and iterative approach to be implemented within a multi-stakeholder framework brought together around a body for the implementation of agricultural insurance.

Keywords: Agricultural insurance, risk, Togo, willingness to pay

Contact Address: Yao Marius Kpani, University of Kara, Lab. of Economics and Management Sciences, Rue Clemence, Lomé, Togo, e-mail: marius.kpani@yahoo.fr

Youth entrepreneurship success: A case study of food processing enterprises in Ghana

Bernard Kwamena Cobbina Essel, Miroslava Bavorová, Ayat Ullah,
Sylvester Amoako Agyemang

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

Youth entrepreneurship has received considerable support in Ghana, but most enterprises, especially those started by young people, still have low success rates. This study aims to map youth entrepreneurs in the food sector and examine the determinants of profit and employment in youth-owned micro and small food processing enterprises in Ghana. Quantitative and qualitative data were collected through face-to-face interviews with 244 young food processors from three regions of Ghana in 2021. The results show that young women (82 %) run most of the businesses, and most operators (50 %) are highly educated. The average age of the enterprises was four years, while eight different food categories were processed. Female entrepreneurs dominate starchy food production (13 %), while the fruit and vegetable sector is dominated by male entrepreneurs. Ordinary least squares (OLS) regression results show that previous experience in a similar business, membership of a business association, age of the entrepreneur and having a mentor are positively correlated with profit. Access to credit from an institution and being located in the Ashanti region were negatively correlated with profit. Furthermore, access to training, having a business partner, the age of the entrepreneur and being in an urban area have a positive effect on job creation, while access to credit, being in the Ashanti region and being male have a negative effect on job creation. The study concludes that the provision of mentors, support for membership of business associations and training through youth entrepreneurship programmes will improve the success of food-based micro and small enterprises.

Keywords: Entrepreneurs, food processing, Ghana, micro-enterprises, youth entrepreneurship

Contact Address: Bernard Kwamena Cobbina Essel, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Kamýcká 129, 16500 Prague-Suchdol, Czech Republic, e-mail: esselb@ftz.czu.cz

Market potential for new hybrid forages for East Africa

John Jairo Junca Paredes, Jesús Fernando Florez, Karen Enciso, Luis Miguel Hernandez, Natalia Triana-Angel, Stefan Burkart

The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia

Dairy production is the main livestock activity in East Africa and provides food security and income to the poorest families in the region. Especially in the drier areas of East Africa, however, the availability of space for dairy farming is limited, leading to pressure for finding alternatives that help maximise its use. Cut-and-carry forages are one such solution, but the commonly used forages in these systems are generally of low quality making it difficult to fully cover the nutritional needs of the animals. Improved forages have shown to be good alternatives for increasing both quantity and quality of feeds in cut-and-carry systems and improving the adaptability to climate change. With the purpose of promoting the sustainability of livestock farming in the region, CIAT has been developing interspecific hybrids of Urochloa, which are on the market since more than a decade, and is also developing hybrids of Megathyrsus maximus adapted to the local productive and environmental conditions. The objective of this document is to estimate the potential markets for new hybrids of these two species in East Africa. With data from secondary sources, GIS studies of geographic environments, seed price databases, and expert consultation, we calculated the size of these potential markets (in ha) and estimated their potential values (in US$). The results indicate a regional market for new interspecific Urochloa hybrids of 352,158 ha with a value of US$ 62,479,997. The main markets are Ethiopia, Tanzania, and Kenya, which make up 83 % of the total market. The potential market for Megathyrsus maximus hybrids is 494,471 ha with a value of US$ 94,648,595. South Sudan, Ethiopia and Tanzania hold a share of 71.63 % in this market. These figures show significant possibilities for the development of a more sophisticated forage hybrid seed system in the region. However, it is necessary to combine this with a favourable environment for adoption. Adequate information systems, seed marketing facilities, and continuous monitoring by extension services are essential for producers to adopt these technologies.

Keywords: Food security, forage hybrids, Megathyrsus maximus, potential markets, sustainability, Urochloa

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Striking the right balance between quality and cost: An analysis of productivity and profitability of value chains of third-wave and non-third-wave coffee smallholders in Central Java, Indonesia

Evi Mariana, Bente Castro-Campos

Justus-Liebig University of Giessen, Inst. of Agricultural Policy and Market Research, Germany

In 2002 the terminology of third-wave coffee value chain was coined, introducing a new organisational structure between coffee producers, roasters, and consumers. The third-wave coffee value chain has seen the emergence of local micro-coffee roasters working directly with smallholder farmers with a vision to offer fairer prices to smallholders and encourage them to improve their coffee quality. However, there is little research on whether third-wave smallholders actually benefit from higher income compared to smallholders who are not part of the third-wave. This study compares the productivity and profitability of coffee smallholders belonging to the third-wave coffee value chain with those belonging to the general value chain. We interviewed a total of 114 Robusta smallholders and 112 Arabica smallholders in Central Java Province, Indonesia in 2021 and 2022, to gain a better understanding of this situation. The data collection included the profile of the coffee farm, the costs of coffee production, and the revenue for the years of 2020 and 2021. The comparison of the farm profile and productivity between the smallholders in the third-wave and those not in the third-wave shows that only the selling price for cherries and green beans are statistically significantly higher for smallholders producing for the third-wave due to the higher quality requirements. In terms of profitability, the analysis shows that third-wave Robusta smallholders generate less profit than non third-wave smallholders in 2020, but more profit than non third-wave smallholders in 2021, suggesting that production costs for higher quality requirements are not necessarily offset by higher prices. However, third-wave Arabica smallholders make more profit than non third-wave smallholders in both 2020 and 2021, suggesting that higher production costs are offset by higher prices. The difference between Robusta and Arabica can be explained by the fact that Robusta generally has lower quality requirements and is less suitable for the third-wave, and that the market price of Robusta is usually lower than the price of Arabica.

Keywords: High-value chain, smallholders' productivity, value chain

Contact Address: Evi Mariana, Justus-Liebig University of Giessen, Institute of Agricultural Policy and Market Research, Senckenbergstraße 3, 35390 Gießen, Germany, e-mail: evi.mariana@agrar.uni-giessen.de

Sustainability and added value in agribusiness production chains: The poultry case

Valquíria Duarte Vieira Rodrigues[1], Alcido Elenor Wander[2],
Fabricia da Silva Rosa[3], Luiz Paulo de Oliveira Silva[4]

[1]*Federal University of Goiás, Law College, Brazil*

[2]*Brazilian Agricultural Research Corporation (EMBRAPA), Brazil*

[3]*Federal University of Santa Catarina (UFSC), Brazil*

[4]*Ministry of Regional Development, Brazil*

This paper aims to analyse the environmental management of sustainable food systems and how this activity has been modifying land use in the poultry production chain. It represents a case study of the poultry value chain in the Brazilian state of Goiás. The studied chain is represented by 13 business organisations, 230 farms, and 816 broiler houses. The exploratory and qualitative investigation involved data collection from primary and secondary sources and applying a questionnaire at all considered chain levels. Forest management practices, waste generation, water resources, energy and emissions, and environmental management accounting were analysed at the chain levels. The study considered those practices from the integrating company and its business units and integrated poultry farms. The main results demonstrate that it is necessary to think about water resources and land use to expand and develop sustainable agrifood systems. Regarding the poultry value chain, there is a direct relationship between freshwater availability and poultry production. In this regard, environmental management is a powerful ally to consider in strategies and practices aimed at mitigating the impacts of the activity and the climate adaptation process of production systems. Among the driving factors for adopting environmental accounting systems are the growing demand from consumers for providers of goods whose impacts generated in the supply chain, production, storage, transportation and commercialisation are duly quantified and disclosed. It is concluded that this research contributes to the development of environmental management practices aligned with the Brazilian agricultural business strategy and the management of natural resources, such as water and land use. Thus, future research can address the influence of these water and land resources on sustainability and competitiveness in the productive chain of poultry production, as well as in diverse chains aimed at agribusiness, agrifood chains and different manufacturing activities.

Keywords: Agribusiness, environmental management accounting, sustainable evelopment

Contact Address: Alcido Elenor Wander, Brazilian Agricultural Research Corporation (EMBRAPA), Rodovia GO-462, km 12, 75375-000 Santo Antonio de Goias, Brazil, e-mail: alcido.wander@embrapa.br

Causes and determinants of post-harvest milk losses among milk producers in Tanzania

CHARLES BYALUGABA LUGAMARA[1], JUSTIN KALISTI URASSA[2],
GOODLUCK DASTAN MASSAWE[2]

[1]*Sokoine University of Agriculture, Dept. of Developm. and Strategic Studies, Tanzania*
[2]*Sokoine University of Agriculture, Dept. of Policy, Planning and Managm., Tanzania*

Tanzania's population increased from 44.9 million people in 2012 to 61.9 million people in 2022 and it is further projected to be 151.3 million in 2050. The projected population growth demands collaborative efforts to increase production and minimise food losses to meet the increasing demand for food, dairy products included. Despite the Tanzanian government's policies, strategies and programmes aimed at increasing production, milk processing and marketing infrastructures for milk and milk products are still weak. Overall milk losses continue to be substantially high. This paper evaluates the causes and determinants of post-harvest milk losses at the milk producers node (households and farms) of Tanzania's milk value chain. Data were collected from 370 household heads and 38 farm managers in both the dry and rain/wet seasons. Generally, study findings show that spillage, spoilage and contamination were the main causes of milk losses at each stage of milk handling (milking, collection, storage and transport to market). In addition, a multilevel mixed effects generalised linear model results show the existence of significant relations between husbandry practices, socio-economic factors, geographical locations, season of production, milk handling facilities, storage facilities, transport means and post-harvest milk losses. Furthermore, market availability, membership to an association and education on post-harvest losses was observed to influence post-harvest milk losses. Therefore, the Tanzanian government should improve extension services to impact knowledge on milk handling practices and milk marketing. In addition, it should improve public infrastructures for easier milk collection, storage and transportation. Strategies or actions targeting to minimise post-harvest milk losses can reduce dependency of Tanzania on milk imports.

Keywords: Households, milk producers, post-harvest milk losses, Tanzania

Contact Address: Justin Kalisti Urassa, Sokoine University of Agriculture, Dept. of Policy, Planning and Management, P. O. Box 3035, Morogoro, Tanzania, e-mail: urassa@sua.ac.tz

Complying with the voluntary sustainability standard: How ready are Thai sugarcane farmers?

Nopasom Sinphurmsukskul

Kasetsart University, Dept. of Agricultural and Resource Economics, Thailand

In recent years, voluntary sustainability standards (VSS), such as Bonsucro, have gained increased recognition among stakeholders in the global sugarcane supply chain. This is because responsible sugarcane production is increasingly being called for by the market. However, the adoption of the Bonsucro standard in Thailand, the third-largest exporter of raw sugar, has been rather slow, with only a small fraction of sugarcane farms in Thailand being certified. For this reason, it is necessary to understand the challenges that Thai sugarcane farmers face when it comes to adopting sustainable practices. To this end, 200 cane farmers in Kanchanaburi province were randomly selected. Farmers of four different farm sizes were interviewed, including very large (>80 ha), large (32–80 ha), mid (10–32 ha), and small-scale (<10 ha) farmers. It was revealed that mid and small-scale farmers in the area were facing many economic and social challenges that hindered them from obtaining Bonsucro certification. For example, they lacked legal rights to use land and water for their cane cultivation, which made them ineligible for certification. Many smallholder cane farmers still had to practice pre-harvest burning and hired labour from neighbouring countries due to their limited access to machine harvesters. Additionally, smallholder farmers did not have the financial means to cope with the rising production costs arising from adopting sustainable practices. Farmers with large and very large farms did not encounter these problems and could obtain certification, but they lacked incentive to do so because certified sugarcane could not secure a premium price in Thailand. Policy recommendations are presented and then discussed.

Keywords: Bonsucro, sugarcane, Thailand, voluntary sustainability standard

Contact Address: Nopasom Sinphurmsukskul, Kasetsart University, Dept. of Agricultural and Resource Economics, 50 Ngamwongwan , 10900 Bangkok, Thailand, e-mail: nopasom@gmail.com

The carbon footprint of beef transportation in Colombia: Market connections and distribution networks

Johana Marcela Castillo[1], Carlos Eduardo Gonzalez[1], Aura Bravo[1], Natalia Triana-Angel[1], Anja Lienert[2], Stefan Burkart[1]

[1]*International Center for Tropical Agriculture (CIA), Colombia*
[2]*University of Hohenheim, Production Theory and Resource Economics, Germany*

Livestock food systems largely contribute to the overall food systems' greenhouse gas (GHG) emissions and are thus put at the centre of global policy and research agendas on mitigation and adaptation. An additional growing concern on the prevalence of globalised animal product value chains and the specialisation of agricultural markets and their environmental pressures over supply networks further adds to this debate. However, detailed quantification of the livestock contribution intensity to the emissions has focused mostly on the farm and the performance of animals' feed intake, rather than on the composition and extension of the beef supply network, a perspective that contributes to further our understanding of the food system's carbon footprint. This research thus used the calculation of food miles to explore the functioning of the Colombian beef market and the emissions entailed in the mobilisation of live animals and processed products in central trade nodes between 2019–2022. The results were compared with emissions derived from the transportation of alternative proteins from animal (chicken, pork, eggs, and milk) and non-animal sources (dry grains). The analysis of bovine products indicates that beef transport was responsible for the highest environmental load, generating on average 25.000 tons CO_2eq, in contrast to alternative proteins, where chicken meat is the biggest culprit (40.000 tons CO_2eq). However, chicken's growing demand has increased the quantities mobilised compared to beef, reflecting a greater efficiency of the chicken supply network per volume mobilised. The relational pattern observed in Colombia's regions pointed out Cali as the leading city in the reception and redistribution of live animals and beef. A strong interaction with neighbouring municipalities in the southwest and the Colombian Amazon configures Cali as a highly central node that, in consequence, concentrates significant pollution. These findings reveal the need to develop comprehensive approaches and strategies to reduce livestock production emissions, acknowledging the vital role that the beef supply network, transportation distances, infrastructure, and technologies play in cattle-derived emissions.

Keywords: Greenhouse gas emissions, livestock emissions, logistic analysis

Status of local feed mills in Nigeria: The case of Akure metropolis

Lydia Adeleke

Federal University of Technology Akure, Dept. of Fisheries and Aquaculture Technology, Nigeria

Quality livestock farmed animals and fish feeds available in Nigeria are sold at exorbitant prices. These high prices are associated with the high cost of importing feed ingredients and equipment used in feed mills. Another factor that is responsible for the current high price of animal feed is the erratic power supply/electricity and cost of getting alternative sources of power. Hence, the need to assess the status of local feed mills, thereby making animal farming/rearing sustainable and attractive to both private and commercial investors and eventually boost food production and food security in the country. This research assessed the status of local feed mills in Akure metropolis in enhancing agriculture development, and expansion in Akure metropolis and Nigeria as a whole. Both primary and secondary data were used in the study. Socioeconomic and Demographic characteristics of the respondents were analysed descriptively, Snowball method was used to locate the Fish Feeds Mills in Akure Metropolis. Results revealed that 69 percent of the respondents were male while 31percent were females; 61 percent were between the active age of 30 and 49 years; also, 70 percent had formal education. Currently, the status of Feed Mill industry in Akure metropolis is experiencing low growth due to high cost of fish feed ingredients which constituting about 60 percent of the total cost of fish production. Other fundamental challenges observed in this study were: lack of funds; technical know-how on the part of the feed millers; poor nutritional value of the locally produced feeds; and provision of storage facilities to prevent spoilage of feeds.

The study also revealed that, among the ten (10) feed mills visited in Akure Metropolis, none of the mills produces solely fish feed: only four (4) combined livestock and fish feeds while the remaining six (6) produces only livestock feeds. There was high concentration in the production of livestock feeds compared to local fish feed production in Akure Metropolis. The study therefore recommends, quick intervention from both the private and public sectors on the observed challenges impeding the development of feed mills in the Metropolis and the Nation at large.

Keywords: Akure, feed mills, modern, Nigeria, status

Fresh food markets, small-food producers and transformative path of food system in Thailand

Buapun Promphakping[1], Mukda Suwannasri[2], Ninlawadee Promphakping[1], Anuwat Pontip[3]

[1]*Khon Kaen University, Research Group on Wellbeing and Sustainable Development (WeSD), Thailand*

[2]*Mahidol University, Innovation for Social and Environmental Management, Amnat Charoen Campus, Thailand*

[3]*Nakhon Phanom University, Fac. of Liberal Arts and Science, Thailand*

The decline of importance of agriculture in the developing world highlights the competing food systems. On the one hand, the local food systems producing food in response to local food demand, and on the other hand, the global and industrial food system that widens the food supply chains in response to the global food demands. Drawing on two research projects, namely the Evolution of Fresh Food Markets in the northeast of Thailand, and the Local Food System (funded by Thailand Science Research and Innovation), this paper seeks to explore competing between two main food systems, and propose a pathway to a more sustainable food system. We found that local markets have been evolved and expanded following to the growing urbanisation. The expansion of local markets is widening the opportunities for smallholders' producers to take their food products, usually fresh, to the markets, meanwhile, is also broaden the outlets of industrial foods. We found that small food producers have been significantly drawing into the supply chains of industrial and global food systems, not only through the raw food products, but also through modern agricultural inputs. While the local food system continues to response to local food demands, in particular in a manner of self-contained in case of staple food (rice), the small producers are increasingly facing the chronic indebtedness, the variation of global market prices and the changing patterns and consumption tastes. We propose a transformative pathway for sustainable local food system by unlocking or breaking the chains to modern input supplies of agro-industries, replacing by converting local materials, such as food wastes, agricultural residues, etc. into organic fertilisers. It is also involved fabricating and nurturing networks among smallholders, such as between those who grow maize and husbandry farmers. In addition, local food produces must be diversified, and markets needed to be enhanced and widened. This path of transformation of food system could heighten the food costs, which can be managed or controlled with redirection of public investments, i.e. the urban food waste management, the development of innovation and appropriate technology for processing agricultural or crop residues into fertilisers, etc.

Keywords: Food chains, fresh food market, small food producers, Thailand

Contact Address: Buapun Promphakping, Khon Kaen University, Research Group on Wellbeing and Sustainable Development (WeSD), 123 Mitraparp Road Muang District, TH 40002 Khon Kaen, Thailand, e-mail: buapun@kku.ac.th

Entrepreneurial innovation pathways of the Amazonian cocoa chocolate value chain: A success associative story in San Martin, Peru

JEIMY KATHERIN FEO MAHECHA[1,2], JEISSON RODRIGUEZ-VALENZUELA[2]

[1]*Technische Universität Dresden, CIPSEM, Germany*
[2]*Corporación Colombiana de Investigación Agropecuaria AGROSAVIA, Obonuco Research Center, Colombia*

COVID-19 and the Ukraine war have affected the agricultural sector, especially Latin America. These consequences are reflected in higher prices for agricultural inputs due to the rise of the US dollar, instability in the price paid for harvested products, drastic shifts to other economic activities by farmers, and unemployment in rural areas. One case that has become evident in the Peruvian Amazon is the cocoa crisis, which is a crop that has been profitable in recent years for peasant and indigenous communities; however, due to its high dependency and low diversification, as well as the poor innovation in the production schemes, it has had an impact on the family economy of smallholders. Therefore, this study sought to analyse the resilience case of a cocoa bean trading company (ABISEO FOODS SAC) that had to transform its business model to intervene in the entire value chain on a small scale in the Juanjui municipality (San Martin, Peru). The methodology implemented was based on a SWOT analysis of the business model, the assessment of the profitability, and other foresight methods. The results showed that the success factors of this company in facing the current crises were based on the following actions: 1. Organizing a group of thirty-six small cocoa farmers who have distinguished themselves for their commitment and product quality; however, they have not been able to diversify their crops. 2. Train the association of cocoa producers created by this company on issues related to good agricultural practices. 3. To decide not to compete with large cocoa marketing companies, but on the contrary, to transform the best quality cocoa beans into chocolates and different derivatives, launching its brand to access local, regional, national, and international markets. 4. Through the consortium between the company, the producers' association, and other stakeholders agreed to apply for environmental calls with agroforestry projects that promote the conservation of forest resources in the Peruvian Amazon and the sustainable use of its ecosystem services. Finally, the results of this study could be used as a baseline for decision-making to transform food systems into equitable and sustainable pathways.

Keywords: Agroindustry, associative Innovation, entrepreneurship, Peruvian Amazon

Contact Address: Jeimy Katherin Feo Mahecha, Technische Universität Dresden, CIPSEM current address: Cra 34 #17-74 apto 301, 520002 Pasto, Colombia, e-mail: jkatherinfm@gmail.com

Local logistics and transport for African indigenous vegetables in sub-Saharan Africa: A case of Kakamega and Vihiga counties in Kenya

Mary Makyao[1], Barbara Lenz[1], Zacharia Mganilwa[2], Prosper Mgaya[2]

[1]Humboldt-Universität zu Berlin, Fac. of Mathematics and Natural Sciences, Inst. of Geography, Germany
[2]National Institute of Transport, Transport Engineering and Technology, Tanzania

African indigenous vegetables (AIVs) are an important source of nutrition and income for smallholder farmers and rural communities in sub-Saharan Africa (SSA), still, there are postharvest losses. Factors that shape the local logistics and transport as the prerequisite for the reduction of postharvest loss are yet to be established with certainty. The main objective of this paper was to investigate the nature and actors in the local logistics and transport of AIVs in SSA. Although several studies give important insights into the functioning of the AIVs supply chain, it remains difficult to understand the complex "interplay" of factors that shape the local logistics and transport of AIVs in SSA. This study deployed a hybrid approach encompassing a literature review, focus group discussions, and interviews. The results indicated that at each stage of a supply chain, there is a specific set of actors. The data from the field survey revealed that farmers have longer periods in AIV activities (30 years) while transporters have short periods (one to 10 years). This implies that farmers had ventured into AIVs investment for 20 years without reliable logistics and transportation services. Also, the results indicate that local logistics and transport of AIVs are shaped by a range of specific factors including; physical, social, cultural, legal, and economic factors. An understanding of the existing logistics and transport for the AIVs' local supply chain may enhance productivity and raise expectations. This can improve the reduction of postharvest losses and consequently improvising the nutritional benefits and community livelihood in rural areas of SSA. The information from this study is useful to AIVs' farmers, transporters, traders, nutritionists, and policy-makers.

Keywords: Actors, African indigenous vegetables, nature, supply chain

Contact Address: Mary Makyao, Humboldt-Universität zu Berlin, Fac. of Mathematics and Natural Sciences, Inst. of Geography, Freiheitsweg 17, 13407 Berlin, Germany, e-mail: mary.makyao@hu-berlin.de

From dumping to upcycling: Modelling environmental and economic impact of coffee cherry uses

Malte Heller, Wady Khawly, Eranda Bandara, Hamzeh Mirzaei, Athena Birkenberg

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Coffee by-products have the potential to contribute to a circular and sustainable bioeconomy by reducing waste and thus, environmental externalities, while also improving farmers' economic situation through additional income. Moreover, agricultural residues such as those from coffee production can serve as the basis for innovative new products. One notable example is the coffee cherry pulp or husk (cascara), a by-product generated during the coffee processing steps in producer countries. Coffee cherry pulp is traditionally used to produce compost and biogas or make tea, jam, or flour. While in recent years dried coffee cherries are increasingly used as the basis for infusions to produce caffeine-containing beverages.

However, utilising by-products is not a cost-free endeavour. Sometimes, new infrastructure needs to be built to re-organise the processing of raw material, or new harvesting techniques must be developed for the by-product. Additionally, creating new value chains may generate additional greenhouse gas emissions.

Thus, it remains unclear which use of the coffee cherry can increase or reduce environmental impacts, such as climate change mitigation, while also creating potential economic gains for farmers.

To address these issues, this study models selected and relevant use scenarios of the coffee cherry (i.e. dumping as the baseline, composting, biogas production, and local tea) with regard to their environmental and economic impacts. A life cycle assessment is carried out for each scenario, along with a cost-benefit analysis. The results will provide valuable insights into use scenarios, which can help inform decision-making regarding the utilisation of coffee by-products and highlight considerations for agricultural by-products in general. By this, the study may contribute to the development of a more circular bioeconomy.

Keywords: By-product, ciruclar bioeconomy, coffee, LCA, upcycling

Contact Address: Athena Birkenberg, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: a.birkenberg@uni-hohenheim.de

How do environmental shocks affect competitors in an agricultural supply chain? Evidence from a competitors' weighting matrix

Federico Ceballos-Sierra[1], Jhorland Ayala-García[2]

[1]*The Alliance of Bioversity International and CIAT, Honduras*
[2]*Banco de la Rep. de Colombia, Centro de Estudios Economicos Regionales, Colombia*

Coffee is one of the major commodities traded in the international markets, where the largest exporters for 2016 were Brazil (39.15 %), Vietnam (34.22 %), Colombia (14.95 %) and the main importers being the United States (20.8 %), Germany (17.4 %), Italy (7.6 %). This paper studies the impact of droughts on coffee production and exports considering droughts happening locally and in competitor countries. We develop a method of estimation that allows us to consider producer countries and competitor countries in the same regression, avoiding the omitted variable problem that can be a source of endogeneity.

Our approach consists of creating a row standardised weighting matrix of competitor countries, where the weights represent the market share of producer countries among all the producers facing the same international demand for the product each year. It is expected that a negative weather shock in a producer country that reduces local coffee production will also reduce the market segment of the same country in the international market. That segment will be captured by the closest competitors. As a result, this paper contributes to the literature by proposing a method for estimating this indirect effect of weather shocks applied to the coffee trade network.

We found that Brazil is the largest competitor for all countries, followed by Vietnam and Colombia, with small changes throughout the period 1995–2019. The results show that droughts reduce local coffee production, although no direct effect on exports was found. In addition, droughts in competitor countries increase local production and exports with a one-year lag, given the time needed for adjusting the growing seasonal production. Our findings are robust to the inclusion of country and time fixed effects, as well as other control variables such as temperature, precipitation, and GDP. These results contribute to the literature studying the mitigating effect of international trade to negative weather shocks. Ignoring the indirect impacts of natural disasters could lead to incorrect conclusions about the impact of extreme weather conditions.

Keywords: Coffee, droughts, spatial spillovers, supply shocks

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Contact Address: Federico Ceballos-Sierra, The Alliance of Bioversity International and CIAT, Col. loma linda norte avenida la fao media cuadra antes de injupemp edificio dicta., 11101 Tegucigalpa, Honduras, e-mail: federico.ceballos@cgiar.org

Strengthening value chains of products from the Amazon: Lessons from and to the "*Gosto da Amazônia*" Project

Daniel Alberto Perozo-Suárez[1,2], Tatiana Rehder[2]

[1]*University of Brasilia, Dept. of Economics, Brazil*
[2]*Instituto Chico Mendes de Conservação da Biodiversidade, Brazil*

Guaranteeing food supply for Brazil's traditional peoples and communities is a challenge in economic, political, environmental, and logistical terms. Indigenous communities and traditional peoples in the Amazon are vulnerable since they make a living in remote areas, with few opportunities for access to conventional markets, hardly considered in public policies, and generally do not have jobs or stable sources of income. However, these communities possess millennial knowledge that, combined with technical knowledge of sustainable management of plant and animal species, offers great opportunities for developing food security and income generation strategies based on biodiversity conservation. The "*Gosto da Amazônia*" Project is an example in this sense. It is the result of an institutional partnership between national and international stakeholders, including Brazilian, American, and German partners(*) that aimed to contribute to improving the quality of life of the communities involved in the management of *Arapaima gigas* (*pirarucu*), one of the largest freshwater fish in Brazil. This is an endangered species whose sustainable management is only possible under authorisation from the environmental authorities. In addition, the sustainably managed value chain competes in the market with the illegally harvested chain. The project's impacts cover the social, economic, environmental, and cultural spheres. The present work proposes a system of baseline indicators to evaluate the scope of the impacts regarding income generation, employment, food security, product positioning, consumer acceptance and choice, cultural influence, size of the stakeholders' network, conservation impacts, and potential for the continuity of the project's effects over time. Among other results, the relevance of strengthening value chains, as well as the permanent work of business management and reinvestment for project sustainability were highlighted as essential factors for the success of this and other initiatives that propose the transformation of current food systems.

Keywords: Amazon, food security, pirarucu, sustainable management, value chains

Contact Address: Daniel Alberto Perozo-Suárez, University of Brasilia, Dept. of Economics, Campus Darcy Ribeiro, 70910-900 Brasilia, Brazil, e-mail: keemoen@gmail.com

Impact of seed innovations on farm performance among African indigenous vegetables producers in western Kenya

Joseph Alulu[1], Robert Mbeche[2], Kavoi M Muendo[2], Dagmar Mithöfer[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci. - Agricultural Economics, Germany*

[2]*Jomo Kenyatta University of Agriculture and Technology, Dept. of Agricultural and Resource Economics, Kenya*

Food insecurity, population growth and urbanisation are major challenges in sub-Saharan Africa (SSA). In East Africa, leafy vegetables that naturally occur and grow from seed after the rainy season have traditionally been used. Informal markets and formal supply chains of these African indigenous vegetables (AIVs) are increasingly developing with a potential to not only contribute to food sufficiency but also diversified diets in terms of micronutrients and vitamins. Despite the growing recognition of the development potential of AIVs, development of AIVs value chains faces constraints such as limited access to appropriate seed innovations and low levels of efficiency. Previous literature has shown that smallholder producers can capitalize on various innovations including seed innovations to overcome these constraints and enhance their performance. In line with the conference theme "Competing pathways for equitable food systems transformation", this study, under the project "Inclusive nutrition-sensitive value chains, upgrading strategies for underutilised horticultural crops in Kenya and Uganda (InNuSens)" sought to assess determinants of adoption of seed innovations and its impact on performance of AIVs producing households, a potential technical solution to climate change phenomenon in food systems. The study incorporates behavioural factors as covariates of adoption of seed innovations. To achieve this objective, the study used multistage sampling approach that led to 445 AIVs producers in Bungoma and Kakamega Counties in Kenya being included. We employ a bias-Corrected Stochastic Meta-Frontier Approach to estimate technical efficiency (TE), allocative efficiency (AE), economic efficiency (EE) and technology gap ratios (TGRs) while accounting for potential technological differences as well as self-selection bias. We specify a stochastic frontier model to estimate meta TE, AE and EE and employ propensity score-matching (PSM) technique to address self-selection bias. Our results reveal that both behavioural and control beliefs have a positive influence on adoption of seed innovations. Empirical results show that adopters outperform their non-adopter counterparts on average in both technical, allocative and economic efficiencies and meta-efficiencies.

Keywords: AIVs, impact, seed innovations, vegetables

Co-creative characterisation of food systems for the generation of transition routes towards their sustainability in indigenous population

Teresa Mosquera-Vásquez[1], Alvaro Acevedo Osorio[1], Luis Alfredo Londono[2], Yesid Aranda[1], Sara Del Castillo[1], Eucaris Olaya[1], David Cuéllar Galvez[1]

[1]*Universidad Nacional de Colombia, sede Bogotá, Colombia*
[2]*Universidad del Cauca, Facu. de Ciencias Agrarias, Colombia*

Highly vulnerable populations such as indigenous peoples are seriously affected in their food and nutrition. The National Survey of the Nutritional Situation Colombia shows that food insecurity in 2015 was at 54.2 %, and that eight out of ten indigenous households are in food insecurity. This situation has been aggravated by climate change, the pandemic generated by COVID 19, the armed conflict in their territories, and recently, by economic phenomena such as inflation, devaluation, unemployment, and increased food prices, as evidenced by various authors and studies. Given the lack of effective results of public policies, alternatives have emerged that are grouped under the generic denomination of "food autonomy" or "food sovereignty". These alternatives constitute a wide universe of practices and proposals from the communities, which gradually intertwine, generating innovative, creative, and locally adapted responses, with interesting results in their contribution to guaranteeing the right to food. These initiatives are inspired by deeply rooted cultural principles and conceptions, many of them are related to territorial control and governance processes and can be understood as counter hegemonic. This set of food practices and social actors involved, are articulated with the dominant food system, but in permanent tension with it, and constitute what can be called "territorial food system". The research project called "Territorio, Comida y Vida" studies food systems at the territorial level in two indigenous populations of Colombia, Misak and Los Pastos, to identify the mechanisms that manage to empower communities and interest groups in the search to reduce inequities and a good life for the most vulnerable. During the presentation, the results of the characterisation of the food systems of these peoples will be discussed, considering the functions, provision and services, collection and co-production, supply, trade and distribution, consumption, waste and unused management, emerging elements, evaluated at the household, farm, reservation, municipality, and other stakeholder levels. For the characterisation, instruments such as surveys, in-depth interviews, focus groups and secondary information are applied. The research methodology will be discussed, which follows a co-creative process and has a transdisciplinary work approach, where gender, inclusion and intersectionality are transversal.

Keywords: Food sovereignty, food autonomy

The impact of COVID-19 lockdown on milk production and marketing activities in Kiboga district

Ninsiima Grace Musumba[1], John Illukor[2], Nakato Caroline Bukirwa[1]

[1]*Makerere University, Dept. of Agribusiness and Natural Resources, Uganda*
[2]*World Bank Group, Uganda*

High and sustained milk production in dairy can only be sustained by regular rainfall, good farming practices such as adequate feeding of cows, disease and pest management and selection of superior animals for breeding. Marketing of milk on the other hand is an important component for achieving profitability and sustainability of a dairy enterprise. World over especially in sub-Saharan Africa, production and marketing of agricultural products were impacted by COVID-19 in various ways. This study therefore was conducted to assess the impact of COVID-19 on production and marketing of milk in Kiboga district.Data was collected from 156 farmers who were randomly selected from the three sub counties in Kiboga district.The collected data was analysed using descriptive statistics, t-tests ans regression models. All the interviewed dairy farmers reported that COVID-19 had affected the production and marketing of their milk. There was a significant difference in the price per litre of milk sold before COVID-19 and after the lockdown was lifted. There was a decline of 1.4 % in the productivity per cow per day during the lock down compared to before the pandemic. there was also a decrease in the average price of a litre of milk sold to dairies 34.9 %, cooperatives 37.3 % and spot markets 10 % during the lock down. After lifting the lock down, the productivity of cows is seen to have gone back to the way it was before the lockdown and the price of a litre of milk is reported to have gone higher than it was before COVID-19. This was because of the increase in the costs of production. There was an increase in the weekly costs of production especially spraying (45 %), and treating cattle (77.6 %). Most of the farmers did nothing to cope up with the decrease in milk prices, reduced the prices charged per litre in order to cope up with he reduction in the number of customers. Government and other stalk holders should reduce on the taxes imposed on inputs like pesticides which have resulted into high production costs.

Keywords: COVID-19, dairy farmers, milk prices, volume of milk sold

Contact Address: Nakato Caroline Bukirwa, College of Agricultural and Environmental Sciences, Makerere University, Department of Agribusiness and Natural Resources, Kampala, Uganda, e-mail: nakatocarolinebukirwa@gmail.com

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Sustainability and agroecology monitoring by private sector companies in the global rice value chain

Dirisa Wakaabu[1], Jonathan Steinke[1], Stefan Sieber[2,1], Harald Grethe[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*

[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Rice is a staple food consumed by over half the world's population and there is a projected production and consumption increase particularly in Asian countries. However, rice production contributes significantly to greenhouse gas emissions and has various negative effects on natural ecosystems. Consumers and policymakers are increasingly demanding evidence of more sustainable rice value chains. Consequently, many private companies involved at different value chain levels, such as inputs, production, packaging and storage, processing, distribution, and marketing of rice already report on the adoption of sustainable practices. Taking an agroecology perspective that distinguishes between five different levels of food system change, this study analyses patterns in sustainability transitions and the reporting gaps. This study conducted a systematic review of sustainability indicators and measurement methods used by 33 private companies with membership in the Sustainable Rice Platform (SRP). Sustainability reports published between 2018 and 2023 were screened to identify the reported sustainability indicators, assess the extent of their adoption, and evaluate their degree of alignment with the 13 principles of agroecology. Most companies attained levels 1 and 2 (farm layers) and 4 (community layer) but very few attain transformative agroecological levels 3 (landscape layer), and 5 (society layer). Performance regarding the agroecological principles; social values and diets, input reduction, and fairness were most reported, whereas synergy, co-creation of knowledge, and land and natural resource governance were least reported, with variations across regions and levels of the value chain. The indicators are measured using digital tools, satellite monitoring, farm visits, and reports from their suppliers, and most companies have reported concerns about data accuracy and completeness. Other bottlenecks include a lack of regular monitoring, confirmation, and verification of certified standards as well as their enforcement, especially in low and middle-income countries. Finally, companies can effectively contribute to a sustainable value chain by committing to ethical and transparent compliance, monitoring, and reporting sustainability indicators, and labeling market products. Thus, interventions such as consumer pressure, strict policies especially in LMICs, and enforcement of certification standards are crucial to accelerating the sustainability transition in global rice value chains.

Keywords: Agroecology, global value chains, rice, sustainability

Contact Address: Dirisa Wakaabu, Humboldt-Universität zu Berlin, Dept. of Agricultural Economics, Berlin, Germany, e-mail: wakaabudirisa@gmail.com

Wheat value chain analysis in Bale zone, Ethiopia

Zera Kedir Alo[1], Jema Haji[2], Amsalu Mitiku Bora[1]

[1]*Jimma University, Agricultural Economics and Agribusiness Management, Ethiopia*
[2]*Haramaya University, Agricultural Economics, Ethiopia*

Value-adding to agricultural commodity is a means to increase farm incomes and to regenerate rural economy. Although farmers are the primary producers and actors of wheat, they were not able to share from the growing market benefit of the product in Ethiopia. This study was aimed at analysing value chain of wheat in Bale zone with the specific objectives of identifying wheat value chain actors and their respective functions, analysing marketing margin of wheat value chain actors and identifying the determinants of wheat market supply by producers. The data were obtained from both primary and secondary sources. The primary data for this study were collected from 201 farmers, wheat traders, wheat processors and wheat consumers following appropriate sampling procedures. Descriptive statistics and Two Stage Least Squares of econometric model were used to analyse the data. Margin analysis was used to estimate the share by each actor involved in wheat value chain. From the result, producers are not governing the value chain. Hence, they are price takers and the whole wheat value chain is governed by processor. The results of margin analysis revealed that 22.29 % and 26.80 % share of margin and profit were captured by wheat producers and 36.63 % and 34.76 % share of margin and profit were captured by wheat processors respectively. The result of Two Stage Least Squares indicated that quantity of wheat produced, sex, memberships to cooperative, lag price of wheat, family size and farming experience significantly influenced volume of wheat sold to market. Policy implications drawn from the study findings include the need to improve the input supply system, improving farmers' know how and experience on wheat production, encouraging females productivity, improving productivity of wheat, strengthening the linkage among wheat value chain actors, encouraging farmers to be member of cooperative, concerning bodies should provide last year price information in the market, strengthening poor profit share and strengthening family planning programmes to reduce the amount of wheat consumption at household level.

Keywords: Cost benefit share, Ethiopia, marketing margin, two-stage least square, value chain analysis, volume of wheat sold

Contact Address: Zera Kedir Alo, Jimma University, Agricultural Economics and Agribusiness Management, 2345 Jimma, Ethiopia, e-mail: kedir.zera@ju.edu.et

Technical efficiency and value addition of hybrid tomato under urban homestead farming in southwest Nigeria

Olusegun Ogunwande

Federal University of Technology Akure, Agricultural and Resource Economics, Nigeria

Food production, processing, distribution and consumption are inevitable activities embarked upon in reversing the upward trend of hunger and poverty globally through profit to producers and utility to consumers. The study measured the technical efficiency and value addition of hybrid tomato under urban homestead in southwest Nigeria. Multistage sampling procedure was used in the selection of 275 respondents which comprised input dealers (50), farmers (100), wholesalers (50) and retailers (75) using copies of well structured and pretested questionnaires administered by trained enumerators. Results of the socioeconomic characteristics for age were average of 51, 64, 49 and 64 years for input dealers, farmers, wholesalers and retailers, respectively, while the mean monthly income for input dealers, farmers, wholesalers and retailers were N66, 843, N40, 556, N73, 061 and N86, 554 respectively. Profit ratio showed the financial performances of the operators in the value addition with input dealer (2.59), farmer (1.22), wholesaler (1.46) and retailer (2.31) suggesting that input dealers had highest financial gain while farmers recorded the least. The mean technical efficiency ratio for the input dealers, farmers, wholesalers and retailers were 0.95. 0.96, 0.53 and 0.75 respectively, which negate the direction of profit ratio. Inaccessibility to farm credit was ranked first among all the constraints identified revealing the acute effect on the activities of all operators along the tomato value chain. It is therefore recommended that government, non-governmental and stakeholder in the business should make funds available to operators in the tomato business to invigourate activities in the food network.

Keywords: Hybrid tomato, urban homestead, value addition

Contact Address: Olusegun Ogunwande, Federal University of Technology Akure, Agricultural and Resource Economics, 10 Fadogba Street, Akure, Nigeria, e-mail: ioogunwande@futa.edu.ng

Food processing, food quality and food safety

Online posters

Hybrid tunnel solar dryer for coffee processing in Colombia: Design and experimental evaluation

Eduardo Duque-Dussan[1], Jan Banout[1], Juan Rodrigo Sanz-Uribe[2]

[1]Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic

[2]National Coffee Research Center of Colombia - Cenicafé, Postharvest, Colombia

Open-sun and solar drying of coffee are used worldwide to lower the moisture content of the beans. Their easy setups and low running costs attract coffee growers; however, these processes are difficult to control and predict due to their dependence on climate conditions. Due to the extended drying time these procedures undergo, the development of microorganisms, mycotoxins and moulds threaten the product. Alternatives such as mechanical dryers are available, allowing to dry large amounts of coffee in shorter times; nevertheless, their running costs and setup are usually expensive and unaffordable for small-scale coffee growers. Therefore, this research aimed to design, build and evaluate a hybrid solar tunnel dryer which mixes solar and mechanical drying principles. It uses a traditional solar tunnel-type dryer as a base featuring a biomass burner which uses coffee trunks left from the yearly crop renovation as biofuel. A heat exchanger heats the drying air, afterwards blown into a plenum chamber that homogenizes the air's static pressure before crossing the coffee bed, ensuring an even moisture removal. Also, the hybrid unit includes a photovoltaic system to obtain a fully self-sufficient drying unit. The newly developed dryer was tested under three different configurations: Solar and mechanical day and night (C1), solar during the day and mechanical during the night (C2) and fully solar with non-mechanical aid (C3). The results displayed a notable drying time reduction in the three evaluated configurations, low biomass consumption and improved temperature and relative humidity profiles. Its design easily adapts to the existing tunnel and parabolic-type solar dryers.

Keywords: Biomass, coffee, coffee drying, hybrid dryer, tunnel dryer

Contact Address: Eduardo Duque-Dussan, Czech University of Life Sciences Prague, Faculty of Tropical AgriSciences, Department of Sustainable Technologies, Kamýcká 129, 16500 Prague, Czech Republic, e-mail: duque_dussan@ftz.czu.cz

Determining sound signature of major insect pests in stored rice using inexpensive acoustic system

Carlito Balingbing[1], Sascha Kirchner[2], Hubertus Siebald[2], Sascha Fiedler[2], Richard Pasco[1], Martin Gummert[3], Nguyen Van Hung[1], Oliver Hensel[2]

[1]*International Rice Research Institute, Sustainable Impact through Rice-based Systems, Philippines*
[2]*University of Kassel, Organic Agricultural Sciences, Germany*
[3]*Consultant, International Rice Research Institute, Philippines*

Insect pests in stored grains can cause a maximum of 10 % losses, but the use of early detection device such as acoustic sensor can prevent subsequent damage in storage. Acoustic detection can directly identify the cause of damage in stored grains (i.e., insects) rather than the effect (e.g., humidity, temperature) as it happens with other sensors, and it is capable of handling high information density due to the broad frequency band and the different sound signature and levels. This research adapted and investigated the applicability of the acoustic sensor from the smart apiculture management system (SAMS) project of Uni Kassel for use in detecting insect pests in stored rice products.

The Adafruit SPH0645, an inexpensive MEMS (micro-electromechanical systems) microphone currently available in the market is an important component of the acoustic detection system that is adapted in this study to detect insect pests in stored rice grains through their sound signature. Three major insect pests that commonly feeds on paddy and milled rice products, namely, lesser grain borer (*Rhyzopertha dominica*), rice weevil (*Sitophilus oryzae*), and red flour beetle (*Tribolium castaneum*) were collected in rice mills and grain storage warehouses in Laguna, Philippines and reared at postharvest laboratory, IRRI, Philippines. Baseline sound recordings for each of the insect were replicated over time for at least 3 days in acoustic shielding chamber. The recorded sounds of the insects in wav file were analysed using R and Audacity softwares to establish specific sound signature of each insects. Insect sounds of major pests in one-ton storage were detected at 0.62 % for *R. dominica*, 0.22 % for *T. castaneum* and 0.58 % for *S. oryzae*, which represents the percentages of lured insects by the attractants used (e.g., red LED and air blower) against the total density of insects in the storage.

The application of machine learning technique will be employed for easy identification of these insects when the acoustic device is deployed in actual storage conditions.

Keywords: Acoustic system, insect pests in rice storage, machine learning, MEMS microphone, sound signature

Contact Address: Carlito Balingbing, International Rice Research Institute, Sustainable Impact through Rice-based Systems, 4030 Los Baños, Philippines, e-mail: c.balingbing@irri.org

Dioxins and polycyclic aromatic hydrocarbons in farmed and wild-harvested edible insects from East Africa

Carolyne Kipkoech[1], Christoph Hutzler[1], Christoph Gottschalk[1], Julia Jaster-Keller[1], Marta Marek[2], Mariko Yamamoto[1], Anke Jährmann[1], Lisa Klusmann[1], Annemarie Richter[1], Alexander Roloff[2], John Mwibanda Wesonga[3], Ronald Maul[4,1], Anja Lüth[1], Stefan Weigel[1]

[1]*German Federal Institute for Risk Assessment (BfR), Dept. Safety in the Food Chain, Germany*
[2]*German Federal Institute for Risk Assessment (BfR), Dept. Chemical and Product Safety, Germany*
[3]*Jomo Kenyatta University of Agriculture and Technology, Kenya*
[4]*Current address: Max Rubner-Institut, Federal Research Institute of Nutrition and Food, Dept. of Safety and Quality of Milk and Fish Products, Germany*

Edible insects offer a sustainable alternative source of animal proteins in food and feed. Although insects are considered highly nutritious and environmentally friendly, there is a risk that they and their products may be contaminated by environmental contaminants during rearing and processing. These substances can be ingested by the insects along with the feed, or they can contaminate the products during processing and storage if done under unfavourable conditions. The presence of hazardous organic chemicals such as dioxins and polycyclic aromatic hydrocarbons (PAHs) should be investigated to ensure safe product consumption. Grasshoppers, termites, crickets, and black soldier fly larvae were purchased from insect traders in Kenya, Uganda, and Tanzania. The dried and ground black soldier fly larvae served as a representative matrix for method validation, including determination of limits of quantitation (LOQ) and limits of detection (LOD). For dioxin analysis, ^{13}C-labeled congeners were added to the samples prior to extraction. Since dioxins accumulate in adipose tissue, fat extraction was performed using dichloromethane/cyclohexane solvent (1:1), and the sample was purified using MIURA's GO-xHT system. The purified extract was measured by high-resolution gas chromatography and high-resolution mass spectrometry (HRGC-HRMS) and quantified by isotope dilution technique. For PAH analysis, samples were extracted by energy dispersive guided extraction with cyclohexane/ethyl acetate (1:1) on an EDGE system. Subsequently, the extracts were purified by gel permeation chromatography, then the fat and protein were separated from PAHs before sample concentration. The method proved to be excellent in terms of extraction efficiency, purity of the extract,

and speed of sample processing. Although PAH analysis has not yet been completed, relatively high levels of naphthalene and phenanthrene were detected in the insect samples. Dioxin contamination varies by insect sample and insect species and is generally low compared to other animal products, as no maximum levels have been established for edible insects.

Keywords: Dioxins, food safety, food security, PAHs, protein

Computational sizing of a hybrid photovoltaic system for peanut oil production in Senegal

Wiomou Joévin Bonzi, Sebastian Romuli, Joachim Müller

University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany

In Senegal, peanut is the first agricultural product. However, only 40 % is locally processed, with 32 % for edible oil. Plant oil extraction faces high cost of electricity and competition from importers. Renewable energy could be a solution, but determining the most profitable renewable system requires consideration of load profile, meteorological data, and economical aspects. This study aimed to develop an approach to sizing a hybrid photovoltaic system through a predictive model of the electrical load of a service-based plant oil processing company. To achieve this, a diagnosis was conducted at the small-scale industry Yaye Aissatou in Passy, Senegal, to evaluate the peanut oil extraction process. The mass and energy balance were measured. The processing capacity was 4 tons of in-shell peanuts per day for 1 ton of oil produced, using 67 kWh of electricity. The process was implemented into MATLAB Simulink to find the load profile. An optimisation was performed to identify the working time, quantity of material, and customer arrival probability matching the diagnosis results. The simulated load profile was implemented in HOMER Pro, along with the meteorological data of the site and the cost of solar components in Senegal, to identify the characteristics of the most profitable hybrid system. The optimal solution presenting the lowest net present cost over 25 years was found to be a grid-connected system with 18.6 kWp solar panels, 16 kWh of storage, and an initial investment of 13.1 million francs CFA. Compared to a grid-only scenario, this solution reduces the net present cost from an initial 47.3 million CFA to 20.7 million CFA, the operating cost from 2.4 million CFA per year to 386,964 CFA per year, and the cost of energy from 193 to 84 CFA kWh^{-1}. The renewable fraction of the proposed system is 90.1 % while the expected payback period is 6.2 years. The study demonstrates the economic feasibility of using photovoltaic energy for plant oil processing and provides insights into the sizing of a hybrid-grid-photovoltaic system.

Keywords: Economic feasibility, load profile, mechanical oil extraction, plant oil, process simulation model, renewable energy, solar energy

Contact Address: Wiomou Joévin Bonzi, University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Garbenstraße 9, 70599 Stuttgart, Germany, e-mail: bonzi.wiomoujoevin@uni-hohenheim.de

Enhancement of antioxidant properties of traditional dairy products with the addition of dried fruits

Janyl Iskakova[1], Jamila Smanalieva[2]

[1]*Kyrgyz-Turkish Manas University, Environmental Engineering Dept., Kyrgyzstan*
[2]*Technische Universitat Dresden, Fac. of Chemistry and Food Chemistry, Germany*

The antioxidant potential of foods plays an essential role in the diet of people since an antioxidant-rich diet may inhibit the negative impact of free radicals. Fruits and berries have high antioxidant activity, due to the content of vitamin C, E, carotene and polyphenol. Casein and other antioxidant enzymes; lactoferrin; conjugated linoleic acid; coenzyme Q10; vitamins C, E, A and D3; equol; uric acid; carotenoids; and mineral activators of antioxidant enzymes of milk also have antioxidant activity. These antioxidants act at different levels of cell defense against free radicals.

In recent years, ethnic products have been gaining popularity in Kyrgyzstan. Ayran, Suzmo, and Kurut are ethnic fermented milk products. Suzmo and Kurut are rich in proteins, which are obtained by dehydration of fermented milk product - Ayran. In order to expand the range of sour-milk products based on Ayran and enhance their antioxidant activity, within the framework of this study, four new recipes of sweet sour-milk Ayran products with the addition of fruit fillers were developed. Dried apricot and pomegranate peel powder were used as fruit fillers. The pomegranate peels were collected from fresh pomegranate juice vendors and dried apricots were obtained in local markets in Bishkek, Kyrgyzstan. Four new recipes were developed: 1) Ayran + dried pomegranate peel 2) Suzmo + dried pomegranate peel 3) Kurut + dried pomegranate peel 4) Suzmo + dried apricots puree. The antioxidant activity and other physicochemical parameters of new developed dairy products with and without fruit fillers were determined.

DPPH (2,2-diphenyl^{-1}-picrylhydrazyl) assay was used to determine antioxidant activity. The inhibitory ability of Ayran and Suzmo with the addition of dried pomegranate peel and dried apricot was significantly higher compared to fermented milk products without fruit fillers. Thus, it can be concluded that the potential for using dried pomegranate peel and apricot to enhance the antioxidant properties of traditional dairy products is high.

Keywords: dried pomegranate peel, ayran, dried apricot, Kurut, Suzmo

Contact Address: Janyl Iskakova, Kyrgyz-Turkish Manas University, Environmental Engineering Dept., 12 mkr. 41-32, 720049 Bishkek, Kyrgyzstan, e-mail: janil.iskakova@gmail.com

Postharvest practices and determinants of potato and tomato losses for appropriate interventions design in Ethiopia

Samuel Mezemir Yimenu[1], Sisay Yefru[1], Bezawit Seifu[1], Geleta Diriba-Shiferaw[1], Samuel Woldeyohanes[1], Tirfe Zegeye[1], Dekeba Moges[1], Bernd Müller[2], Anis Dzankovic[2]

[1]*Arsi University, Ethiopia*

[2]*Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Germany*

Postharvest loss reduction is an important strategy for food and nutrition security in developing countries like Ethiopia. In the target survey areas, postharvest losses of potato and tomato crops occur at various stages. Therefore, the present baseline survey was undertaken to identify existing postharvest practices and losses that occurred in the supply chain of potatoes and tomatoes in Arsi Zone, Ethiopia. In addition, responsible determinant factors that influence postharvest losses were analyzed. A multistage sampling procedure, through a combination of purposive and simple random sampling techniques, was adopted in the selection of kebeles and households. A total of 209 and 191 smallholder potato and tomato farmers were interviewed in Tiyo and Ziway-dugda districts, respectively. The survey was undertaken in 2022. Quantitative data collection was carried out online using computer-assisted personal interviewing by programming a semi-structured questionnaire in KoboCollect software for tablets. Descriptive statistics (for socio-demographic, postharvest practices, and loss data) and the ordinal probit regression model (for postharvest loss determinant factors) were used to analyze the collected data. From the perspective of the farmers, the primary causes of losses were poor storage facilities, insects and worms as well poor handling techniques. During the harvest stage, working family members significantly ($p < 0.01$) increased potato loss while years of schooling ($p < 0.05$) and harvesting using leaf color change as a criterion ($p < 0.01$) had significantly mitigated it. In storage, female respondents ($p < 0.05$), land size ($p < 0.05$), and lack of training ($p < 0.1$) had accentuated potato loss. During transport, the household age reduced ($p < 0.1$) potato loss whereas farming experience promoted ($p < 0.1$) it. Similarly, during tomato harvesting, the time of harvest mitigated losses ($p < 0.01$), while farming experience and lack of training increased losses ($p < 0.1$). In storage, age, schooling years, sex, and training mitigated tomato losses ($p < 0.05$), while only land size ($p < 0.01$) accentuated it. During transport, land size ($p < 0.05$) and animal-pulled carts ($p < 0.1$) accentuated tomato losses. The awareness of the farmers on proper operation during harvesting, field handling, storage, and transportation should be increased. Suggested interventions include postharvest knowledge and skill training, simple innovative eco-friendly storages constructed using locally available materials, appropriate packaging, and simple value addition and preservation techniques.

Keywords: Loss determinant factor, ordinal probit regression model, postharvest loss

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Contact Address: Samuel Mezemir Yimenu, Arsi University, Dept. of Food Science and Postharvest Technology, 193 Asella, Ethiopia, e-mail: samuelmezemir@arsiun.edu.et

Fast and gentle solar-sorptive drying of fruit and spices with energy efficient water recovery

Tamara Annabelle Theimel[1], Henner Kerskes[1], Tobias Klaus[2]

[1]*Institute for Building Energetics, Thermotechnology and Energy Storage, Sorption Technology, Germany*
[2]*ECOLOG Institute for Social-Ecological Research and Education, Germany*

To make fruit and spices more durable and free from contamination - such as dust, animals or even germs - there are different solar tunnel and green house dryers being investigated and also already commercially available. Most of them are only supported by solar energy and still depend on fossil fuels such as wood or gas to reach the needed temperatures especially when the humidity of the ambient air is already high.

The aim is thus, to develop a concept which is only solar driven by combining a greenhouse dryer with an adsorption process. By drying and heating up the process air via adsorption before entering the green house, the air can take up a lot more moisture from the goods to be dried and thus accelerate the drying process. This also makes gentle drying at low temperatures possible for delicate goods which otherwise will lose valuable flavors or aetheric oils. Solar thermal energy is used for the desorbing process. As a side-product, the water from the desorption process can be condensed to be used as drinking water or to wash the drying goods.

The authors aim to work on a common project to implement this concept e.g. for drying spices in Sansibar, which is one of the world's most arid regions with very little precipitation, contaminated ground water and at the same time very high average ambient humidity. Thus, the majority of the inhabitants has no access to hygienically safe drinking water. Therefore, this concept would bring a double benefit for food and nutrition security in Sansibar or comparable locations.

In the contribution, results from laboratory experiments and simulation studies are discussed and a first demonstrator will be presented.

Contact Address: Tamara Annabelle Theimel, Institute for Building Energetics, Thermotechnology and Energy Storage, Sorption Technology, Pfaffenwaldring 10, 70550 Stuttgart, Germany, e-mail: theimel@igte.uni-stuttgart.de

ID 386

Solar food processing by drying in an off-grid system in Kenya

Alexander Morgenstern[1], Matthias Fischer[2], Albert Esper[2], Morine Mukami[3], Linus Kosambo Ayoo[4], Huxley Mae Makonde[5], James Mwaluma[3], Peter Odote[3]

[1]*Fraunhofer-Institute for Solar Energy Systems ISE, Heating and Cooling Technologies, Germany*

[2]*Innotech Ingenieursgesellschaft mbH, Germany*

[3]*Kenya Marine and Fisheries Research Institute (KMFRI), Kenya*

[4]*Kenya Industrial Research and Development Institute, Kenya*

[5]*Technical University of Mombasa (TUM), Kenya*

In coastal Kenya, lack of cold storage facilities and appropriate technologies result in losses of harvested and fresh products. Coastal fishermen as well as farmers suffer from this situation as they are forced to sell their produce as soon as possible fresh, to dealers or at uneconomical prices. The warm weather in the region also hastens spoilage, especially of fish. Sun drying on open grounds is prone to contamination and produce poor quality fish that cannot gain access to high value markets.

The project SolCoolDry, supported by the Federal Ministry of Food and Agriculture (BMEL), aims to support the fisherman and farmers by the development and set-up of a 100 % solar powered, off-grid system for drying beside the production of ice. The system using solar thermal energy designed to provide a 24-hour operation of the solar tunnel dryer. Degradation processes of the material to be dried during night hours can therewith be avoided. The overall system consists of a sea container shaded by a roof of PV-modules and solar thermal collectors. All additional electric components to power the ice machine are installed in the container. Next to it, two solar tunnel driers have been set up – one with solar thermal support for optimised night operation and the other as simple stand-alone solar dryer. Using a monitoring system allows the partners to keep an eye from remote at the operation behaviour and to support the local operators.

For test and demonstration of the capacity as well as for training purposes different tests of the driers where conducted. With both dryers, excellent product quality could be achieved for various types of fish and several fruits and vegetables, while drying time was significantly reduced compared to conventional methods. By means of a novel concept of loading, the capacity of the installed dryers can be increased up to double, which also allows larger drying batches. In the test runs, it was shown that the overnight heat supply is effective: the heat was transferred to the product and the drying process could be continued throughout the night at 5–10 Kelvin above ambient temperature.

Keywords: Drying, food processing, off grid, solar

Contact Address: Alexander Morgenstern, Fraunhofer-Institute for Solar Energy Systems ISE, Heating and Cooling Technologies, Heidenhofstr. 2, 79110 Freiburg, Germany, e-mail: alexander.morgenstern@ise.fraunhofer.de

Technical evaluation of a solar-biomass flatbed dryer for maize cobs drying in Rwanda

Janvier Ntwali, Sebastian Romuli, Joévin Wiomou, Bonzi, Joachim Müller

University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany

The persistent problem of postharvest losses in the maize value chain poses an arduous challenge for smallholder farmers in Rwanda, ultimately reducing their market bargaining power. As a consequence, there is an exacerbated disparity in revenues that makes farmers, predominantly female farmers, more vulnerable. The existing drying facilities are based on ambient air drying with a long drying time and the alternative mechanical dryers use mostly fossil fuels which is not a sustainable solution. A solar-biomass hybrid flatbed dryer for maize cobs drying was designed and constructed in the high-altitude volcanic zone of Rwanda. The objective was to provide farmers with an affordable and sustainable drying system with a high drying rate compared to the existing method. In this study, we present the results of the technical evaluation of the dryer to rate its capacity to dry maize cobs to the recommended moisture content. Energy balance was assessed by temperature sensors, airflow distribution was measured with a vane anemometer and the solar radiation from weather station were compared to the solar system data recorded through a datalogging charge controller. Maize was dried in three batches and the moisture content was measure with oven method. Results showed a uniform distribution of airflow on the dryer perforated flow. The burner consumed on average 6 kg of empty cobs per hour and the burner efficiency was 59.4 %. The solar system provided a maximum daily yield of 2.6 kWh, and the battery was able to maintain the system during days of low solar energy availability. Maize cobs were dried from an average moisture content of 23.0 % to 13.7 % in an average period of 90.6 hours. This drying time was significantly lower compared to the already existing system which uses more than 6 weeks. The results prove that the solar-biomass hybrid flatbed dryer was appropriate for drying maize cobs to the recommended moisture content and thus reduce the risk of postharvest losses in maize value chain in Rwanda. The dryer might be further improved by combining the burner with a solar heating system to further reduce the biomass mass consumption.

Keywords: Biomass energy, energy balance, maize drying, photovoltaic, postharvest, renewable energy

Contact Address: Janvier Ntwali, University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Garbenstr. 9, 70599 Stuttgart, Germany, e-mail: janvier.ntwali@uni-hohenheim.de

Evaluation of contact toxicity of essential oils for *Sitophilus zeamais* control

Talia Silva Ribeiro, Gisele Lopes de Oliveira, Taina Soraia Muller, Luanna Chácara Pires

Federal University of the South of Bahia, Brazil

The maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae), is a pest responsible for significant damage to stored grains worldwide. Currently, it is managed through chemical control. This study aimed to evaluate the effectiveness of *Cordia verbanancea* and *Protium heptaphyllum* resin essential oils, and *Piper macedoi* hydrolate in controlling *S. zeamais* adults. The study was conducted in the extreme south of the state of Bahia, in the northeast of Brazil, a region known for its large number of small farmers, which makes production losses even more impactful for the local economy. Tests were performed in B.O.D. chambers (T°: $25 \pm 3°C$, RH: $65 \pm 5\%$, and photoperiod: 12 h) to evaluate the mortality of the pest in a completely randomised experimental design. In the first bioassay, Petri dishes containing 13 adult insects each, were submitted to a 20 μl dosage of the corresponding essential oil. The percentage of insect mortality was evaluated after 0, 12, 24, and 48 hours of incubation. In the second bioassay, Petri dishes containing 20 adult insects and 10 g of maize were used, to test four different dosages of *P. heptaphyllum* essential oil (62.5, 125, 500, and 1000 ppm). The number of dead individuals was evaluated after 0, 12, 24, 48, 72, and 96 h of incubation. Positive and negative controls were performed for both assays. The data obtained were analysed with R® software. In the first experiment, it was found that the essential oil of *P. heptaphyllum* resin presented 38.5% efficacy in controlling *S. zeamais* compared to the essential oil of *C. verbanancea* and *P. macedoi* hydrolate. In the second experiment, no statistically significant differences ($p > 0.05$) were observed in the insecticidal effect among the dosages tested for *P. heptaphyllum* oil, although it was evident after 48 hours of incubation and gradually increasing until 96 hours. During the first hours of exposure, a repellant effect was observed, evidenced by the insect's behaviour. It led to the conclusion that **P. heptaphyllum** resin essential oil has toxic action against *S. zeamais* adults. However, further investigation is required to determine the ideal concentration of that essential oil for *S. zeamais* control.

Keywords: Corn storage, insecticidal, maize weevil

Contact Address: Taina Soraia Muller, Federal University of the South of Bahia, Master's Degree Programme in Science and Sustainability, Rua América Latina n° 491 Recanto do Lago, 45987132 Teixeira de Freitas, Brazil, e-mail: tainamuller@ufsb.edu.br

Performance of locally made low-cost evaporative cooling pad alternative to commercial pad

Yetenayet Bekele Tola, Tolcha Techane, Hayat Mohammed

Jimma University, Dept. of Post-Harvest Management, Ethiopia

The dry and hot climate in Ethiopia's rift valley areas significantly impacts the postharvest life of fruits and vegetables. The loss is mainly due to a need for cooling facilities along the supply chain from harvesting to final marketing. Commercial mechanical refrigerators are expensive and beyond the capacity of local farmers and value chain actors to use in different stages of postharvest activities. However, evaporative cooling (EC) rooms can be constructed for dry and hot climates, but the pad is not locally available or expensive. This work attempted to develop a low-cost EC pad as a component of a low-cost EC system to replace the commercial pad. A fiber from the Enset plant (*Ensete ventricosum*) was used as a cellulose fiber to construct a $1\,\text{m} \times 0.5\,\text{m} \times 0.5\,\text{m}$ wetting pad using galvanized metal. Air was pressurized through an equal-sized galvanized metal tunnel using a 300-watt air fan; however, water was continuously pumped from the water reservoir and sprinkled on the top of the pad using a 120-watt water pump. Air velocity (m/s), pad thickness (cm), water flow rate (m^3/s), and fiber orientation(vertical versus horizontal)) at different levels were independent variables to investigate the performance of the pad. The study showed that EC efficiency varied from 70.5 ± 3.5 to $87.2 \pm 5.8\,\%$. The horizontal orientation of fiber at $18\,\text{cm}$ thickness with the lowest air velocity ($1.053\,\text{m/s}$) and water flow rate of $0.15\,\text{m}^3$/s resulted in the most inadequate performance as compared to the highest with similar fiber orientation at $32\,\text{cm}$ thickness, $2.6\,\text{m/s}$ airflow, and $0.23\,\text{m}^3$ /s water flow rates. At the highest EC efficiency, the temperature inside the chamber was lower than outside by 5.9oC, and the RH increased by $29.3\,\%$. Results from the study indicated that a low-cost EC pad could be constructed from locally available resources to replace the expensive commercial pad.

Keywords: Cooling efficiency, evaporative cooling, food loss, postharvest, Rift Valley

Contact Address: Yetenayet Bekele Tola, Jimma University, Dept. of Post-Harvest Management, Jimma, Ethiopia, e-mail: yetenayet@gmail.com

ID 903

Assessing the impact of urbanisation on milk quality and safety: A study in Bengaluru's metropolitan dairy farming systems

Md Shahin Alam[1], Mullakkalparambil Velayudhan Silpa[2], Regina Roessler[3], Anjumoni Mech[4], Pradeep K. Malik[4], Raghavendra Bhatta[4], Sven König[2], Eva Schlecht[1]

[1]*University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany*

[2]*Justus-Liebig University Giessen, Inst. of Animal Breeding and Genetics, Germany*

[3]*University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany*

[4]*National Institute of Animal Nutrition and Physiology, Bengaluru, India*

The complex interplay of rapid urbanisation with a rising demand for quality food in India adversely impacts on the production of fresh milk in urbanising areas; in particular, sourcing dairy cattle feed is increasingly challenging. This leads farmers to incorporate alternative feedstuffs, such as roadside vegetation or food waste, in their cows' rations. This may affect milk safety and composition, including its fatty acid (FA) profile and heavy metal (HM) content. However, these variables are also influenced by cattle breed and season. An investigation was carried out in southern India to explore the effects of urbanisation on the quality and safety of milk, with a focus on FA profile and HM concentration. The study included 39 farmers situated in urban and peri-urban regions of the Bengaluru metropolitan area. During three visits in winter 2021 (n=74 records), monsoon 2021 (n=61), and summer 2022 (n=104), information on farm management was collected along with feed and milk samples. Selected FA and HM analyses for milk were performed by gas chromatography and inductively coupled plasma, respectively, and a mixed model approach for statistical analysis was implemented in R. Milk yield was significantly affected by location and season, with cows in urban locations and in winter season exhibiting highest milk yield. Milk from urban cows contained more unsaturated FAs than milk from peri-urban cows (11 %). Similarly, summer season milk contained more unsaturated FAs than milk collected during winter and monsoon (5 %). There was no difference in milk yield and FA profile between cattle breeds (Jersey, HF, native zebus and their crossbreeds). None of the milk samples contained arsenic and cadmium, whereas chromium and lead were detected in 60 % and 28 % of the milk samples. Thereby, the average concentrations of chromium $(0.011 \pm 0.014 \, \text{mg kg}^{-1})$ and lead $(0.019 \pm 0.053 \, \text{mg kg}^{-1})$ were within permissi-

Contact Address: Md Shahin Alam, University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Steinstrasse 19, 37213 Witzenhausen, Germany, e-mail: shahindps@uni-kassel.de

ble limits as recommended by WHO. In conclusion, the high concentration of unsaturated FAs in milk from urban cows suggests that land-constrained farmers manage to supply a high-quality product to urban consumers by using alternative feedstuffs. Since its HM content is not of concern, fresh cow milk is safe for consumers, even in a highly urbanized setting.

The nutrient composition of leaves from multiple defoliated grain amaranth (*Amaranthus cruentus*)

RACHEL BYARUGABA[1,2], DOROTHY NAKIMBUGWE[2], SUSANNE HUYSKENS-KEIL[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany*

[2]*Makerere University, Dept. of Food Technology and Nutrition, Uganda*

Amaranthus spp. is an indigenous African vegetable with health promoting components that can be successfully cultivated for leaf or grain. A significant amount of work has been done on developing food products from grain amaranth. However, the leaves from the same plants remain an untapped resource as far as high value food products are concerned. In a dual-use production system where there is utilization of the leaves as well as seeds, nutritional and economic value can be enhanced. The aim of this study was to determine the nutrient and health promoting compound composition of the leaves from grain amaranth plants (*Amarantus cruentus*) that had undergone multiple defoliation as is practised in a dual-use system. The study is part of the project "Inclusive nutrition-sensitive value chains in Kenya and Uganda – Upgrading strategies for underutilised horticultural crops (InNuSens)" which is funded by the German Federal Ministry of Education and Research (BMBF) and the German Academic Exchange Service (DAAD). *A. cruentus* seeds were grown under field conditions in Luwero district, Uganda in a randomized complete block design with four blocks. Treatments were based on timing and frequency of defoliation of leaves. Plants were defoliated by removing 50% of the leaves once at 3, 5, 7 and 9 weeks after sowing as well as defoliated twice consecutively using the same leaf harvest intensity at 5, 7 and 9 weeks after sowing. After harvesting, fresh leaves were analysed for β-carotene, total chlorophyll, protein, iron, zinc and calcium and furthermore for health promoting compounds such as phenolics and flavonoids contents. Plant height, dried plant biomass and grain yield at harvest were also measured. Results showed that the β-carotene content significantly increased with maturity stage while multiple defoliation had no significant effect on the same. The protein content remained stable regardless of defoliation frequency. Plant height and grain yield were not significantly affected by the timing and frequency of defoliation. Further results will be discussed in detail.

Keywords: *Amaranthus* spp., defoliation, dual-use, nutrient, phenolics

Contact Address: Rachel Byarugaba, Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Lentzeallee 55, Berlin, Germany, e-mail: rachel.byarugaba@hu-berlin.de

Public taps: A drop in the bucket?
Experimental evidence from Uganda

Femke Maes, Bart Defloor

Ghent University, Department of Economics and Business Administration, Belgium

Lack of access to potable water is one of the greatest challenges for rural regions in developing countries, particularly in sub-Saharan Africa (SSA). Deprivation of potable water causes high rates of morbidity and mortality due to diarrhoeal disease, mainly in children below five years. One solution is to improve the water sources at which drinking water is daily fetched by installing public taps in the centre of towns. While these taps provide communities with safe drinking water, they also require behavioural changes in expenditures since water is no longer free. This study investigates the causal impact of public taps on drinking water quality at home and diarrheal disease. 360 households located in five villages in rural Western Uganda participated. The households were surveyed and a water sample was taken from their storage container, before and after the installation of nine public taps at the village centres. Difference-in-differences analysis suggests that tap use has a limited positive impact on microbiological drinking water quality at home, however, there is an increase in the incidence of diarrhea in children. We show that when households commit to tap water, access frictions and substitution of disinfection limit the potential benefits of public taps.

Contact Address: Femke Maes, Ghent University, Department of Economics and Business Administration, Tweekerkenstraat 2, 9000 Gent, Belgium, e-mail: femke.maes@ugent.be

Germination enhances the multi-nutritional properties of pigmented rice revealed through metabolomic and machine-learning techniques

Rhowell Jr. Tiozon[1], Nese Sreenivasulu[1], Saleh Alseekh[2], Kristel Sartagoda[1], Alisdair Fernie[2]

[1]*International Rice Research Institute (IRRI), Philippines*
[2]*Max Planck Institute of Molecular Plant Physiology, Germany*

Enhancing the dietary properties of rice is crucial to contribute to alleviating hidden hunger and non-communicable diseases in rice-consuming countries. Germination is a bioprocessing approach to increase the nutritional properties of seeds. However, there is scarce information on how germination impacts the overall nutritional profile of pigmented rice sprouts. Herein, we demonstrated that germination could increase certain dietary compounds, such as phenolics, GABA, and micronutrients, and induce new flavonoid glycosides. Minerals such as Ca, Na, Fe, Zn, and vitamins such as riboflavin and biotin increased upon germination. In addition, this process decreased toxic elements like aluminum. This process allowed for a decrease in bound phenolics leading to an increase in free phenolics, corroborating the increased minerals. Metabolomic analysis revealed the preferential accumulation of flavonoid compounds in the germination process. Genome-wide association studies of the altered metabolites revealed the activation of specific genes responsible for increasing certain flavonoid compounds. Notably, the activation of the CHS1 gene boosted the naringenin and the compounds along this pathway. Likewise, the UGT gene is responsible for the formation of flavonoid glycosides derived from kaempferol, caffeic, ferulic, and quercetin. Haplotype analyses showed a significant difference ($p < 0.05$) between alleles associated with this genetic region. Genetic markers associated with these flavonoids were incorporated into the random forest model, improving the accuracy from 89.7 % to 97.7 %. Consistent with this feature, the improved model has a faster prediction speed in a shorter training time. The elite cultivars can breed rice with multi-nutritional properties, and the model could screen rice with several dietary benefits.

Keywords: Germination, machine-learning, metabolomics, rice

Contact Address: Rhowell Jr. Tiozon, International Rice Research Institute, Consumer-driven Grain Quality and Nutrition Center, International rice research institute pili drive ave up los banos laguna, 4031 Laguna, Philippines, e-mail: r.tiozon@irri.org

Chemical characteristics and acceptability of cereal-cricket composite porridge

Danstone Aboge[1], Mary Orinda[2], Silvenus Konyole[3]

[1]*Jaramogi Oginga Odinga University of Science and Technology, Plant, Animal and Food Sciences, Kenya*

[2]*Jaramogi Oginga Odinga University of Science and Technology, Agricultural Economics and Agribusiness Management, Kenya*

[3]*Masinde Muliro University of Science and Technology, Nutritional Sciences, Kenya*

Undernutrition impacts the lives of many young children in sub-Saharan Africa and it is mainly attributed to low quality diets. Using soybean as a rich source of protein in fortification of cereal-based complementary foods is currently costly and unsustainable, underscoring the need for alternative protein sources. This study evaluated the potential of crickets as substitute for soybean in enriching complementary porridge, owing to their nutritional quality and environmental benefits. Four treatment flours denoted as; CP, CPB1, CPB2 and CPB3 were formulated. Control flour, CP was a composite of maize, wheat and defatted soybean flours in the ratio of 2:1:1 respectively resembling a local infant formula in Kenya. The other flours were formulated in the same ratio but with substitution of soybean with cricket flour at 25 %, 50 % and 75 % respectively. The flours were analysed for nutritional composition, *in vitro* protein digestibility and functional properties using standard methods. Porridges developed from the flours were evaluated for sensory attributes on a 9 point hedonic rating scale by women of reproductive age. A significant increase was observed in the following nutrients from CP to CPB3; protein, fibre, fats, potassium, sodium, magnesium, and zinc. Similarly, the *in vitro* protein digestibility of the flours improved from 79.45 $\pm$ 0.21 to 88.67 $\pm$ 0.33 percent. However, a significant decrease was observed in carbohydrate, calcium, phosphorus and iron. Further, a significant decrease was observed in the viscosity of cold and warm porridge, bulk density, water absorption capacity and protein water solubility of the flours. The overall acceptability of the porridges were as follows CP (8.5 $\pm$ 0.72), CPB1 (7.08 $\pm$ 0.94), CPB2 (5.75 $\pm$ 1.53) and CPB3 (3.60 $\pm$ 1.95). Substitution of soybean with cricket flour improved some nutrient content, *in vitro* protein digestibility, bulk density of the flours and viscosity of porridges, but made their porridges less acceptable. There is need therefore to improve the sensory attributes of the cricket-based porridges to increase their acceptability without compromising their nutritional quality.

Keywords: Complementary feeding, edible insects, food security, nutrition, protein

Contact Address: Danstone Aboge, Jaramogi Oginga Odinga University of Science and Technology, Plant, Animal and Food Sciences, Postal address; 210-40601, Bondo-Kenya, 00100 Bondo, Kenya, e-mail: danstoneochieng@gmail.com

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Effect of processing methods on the nutritional composition flours and sensory properties of cake from bambara and pigeon pea flour

Gbolahan Alagbe[1], Olajumoke A. Alagbe[2], Klára Urbanová[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic*
[2]*Forestry Research Institute of Nigeria, Sustainable Forest Management Department, Nigeria*

The effect of roasting and malting on the nutritional composition of Bambara nut and pigeon pea flour and the sensory characteristics of cake made from it were investigated. The Bambara nut and pigeon pea were malted (72 hrs) and roasted (150°C), thereafter milled into flour. The flour was passed through a 0.5 mm screen to remove particle clumps. The flour obtained was subjected to proximate, functional and mineral analysis, while the cake made from the flours were subjected to sensory evaluation to determine the effect of the processing methods. Results obtained showed that there was significant difference ($p < 0.05$) in the proximate and mineral composition of both flours. Proximate composition of the flours ranged from 1.74 to 2.87 % Ash, 2.87 to 3.58 % crude fibre, 2.93 to 4.74 % fat, 17.70 to 21.31 % crude protein and 54.41 to 60.36 % total carbohydrate. Protein values were highest in pigeon pea from both processing methods (21.31 for malting and 20.35 for roasting) while Bambara nut flour had the highest values in both crude fibre and fat contents from both processing methods. Results of the functional properties ranged from 2.73 to 3.1 ml g^{-1} water absorption capacity, 2.06 to 2.16 ml g^{-1} oil absorption capacity, 0.60 to 0.72 g cm^{-2} bulk density and 5.28 to 6.62 % swelling index. The sensory evaluation of the cake made from the flours had no significant difference ($p < 0.05$), while the overall acceptability have some significant difference ($p < 0.05$), with cake made from malted pigeon pea flour having the most overall acceptability score (7.45). These findings suggest that germination could be a beneficial processing method for improving the nutritional and sensory quality of Bambara nut and pigeon pea flour, thus increasing their utilisation in food products.

Keywords: Bambara nuts, nutritional composition, pigeon pea, processing methods, sensory properties

Evaluation of temperature and energy requirements for gari processing at standard quality parameters in Togo

Chikonkolo Mwewa Mwape[1], Aditya Parmar[2], Yaovi Ouézou Azouma†[3],
Komi Agboka[3], Heike Hoedt[4], Wolfgang Scheffler[4], Marcelo Precoppe[2],
Nwabisa Mehlomakulu[5], Solethu Nkosi[6], Emmambux Naushad M.[5],
Mmantsae Diale[7], Oliver Hensel[1]

[1]University of Kassel, Agricultural and Biosystems Engineering, Germany

[2]University of Greenwich, Natural Resources Institute, Food and Markets Department, United Kingdom

[3]Université de Lomé, Ecole Supérieure d'Agronomie, Togo

[4]Simply Solar Scheffler Technology and Consulting, Germany

[5]University of Pretoria, Dept. of Consumer and Food Sciences, South Africa

[6]University of Limpopo, Dept. of Physics, South Africa

[7]University of Pretoria, Dept. of Physics, South Africa

Cassava is a vital staple crop in sub-Saharan Africa (SSA) and plays a significant role in the region's food security. The crop is well adapted to the region's climate and can tolerate drought and poor soil conditions, making it an important food source for communities in rural areas. Over 300 million people in SSA are estimated to rely on cassava as a primary source of calories. However, it has a limited shelf life of one to two days. It can be processed into shelf-stable gari, a partially pre-gelatinized dry granulated cassava product, and is a staple food for millions of people in West Africa. The fermentation process during gari processing generally reduces cyanide to safety levels (10 ppm-WHO). Nevertheless, roasting, the last stage in gari processing, is one of the major bottlenecks and data on the temperature/energy requirements and process duration is scant and sporadic. Therefore, the objective was to determine the temperature and energy requirements for the roasting process at the traditional and cooperative level in Togo using a low-cost semi-controlled cooking tests method (SCCT). The mean specific energy consumption found to produce a kg of gari from dewatered cassava mash (48 % moisture content (MC) to gari (6.7 % MC) from the nine cookstoves evaluated was 7.37 kWh kg^{-1}. The roasting process alone accounted for 96.74 % of the energy consumed, which include combustion chamber, roasting pan surface, gari, and ambient temperatures of 494 °C, 142 °C, 110 °C and 33 °C, respectively. Out of the 114 batches examined, the average batch size was 2.7 kg dewatered cassava mash and 1.6 kg output gari within 20 minutes. Furthermore, a strong correlation (R^2) of 0.88 between the data of the specific energy consumption

Contact Address: Chikonkolo Mwewa Mwape, University of Kassel, Agricultural and Biosystems Engineering, Nordbahnhoftstraße 1a, 37213 Witzenhausen, Germany, e-mail: chikonkolo@uni-kassel.de

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was achieved and agreed with other researchers. Overall, the outcome from this work will help improve energy efficiency, promote sustainability, enhance food security, drive economic development, and advance knowledge in the field of cassava processing. By addressing critical challenges in the production of this vital food product, the study can contribute to improving the livelihoods of millions of people in SSA.

Keywords: Cassava, cookstoves, gari, semi-controlled cooking tests, specific energy consumption, temperature

Micronutrients and secondary plant metabolites composition of commonly consumed African indigenous vegetables from Tanzania

James Simon Chacha, Nadja Förster, Susanne Huyskens-Keil,
Christian Ulrichs, Constance Rybak

Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany

The "triple burden of malnutrition" (TBM), meaning the coexistence of undernutrition, overweight and obesity and micronutrient deficiencies, is a growing challenge in sub-Saharan Africa. Nutrition transition refers to changes in lifestyle and dietary patterns driven by ongoing urbanisation, globalisation and economic growth and is rapidly taking place also in Tanzania. The FoCo-Active project therefore fosters to modify food and physical activity environments including the implementation of a health literacy programme to holistically combat TBM in rural and urban Tanzania. Nutrition-sensitive interventions linked to horticultural production and post-harvest treatments have the potential to improve local food environments by increasing the availability of affordable nutrient-dense vegetables. Simple low-cost horticultural production systems such as flat and bag gardens with associated nutrient-sensitive post-harvest treatments of African indigenous vegetables (AIVs) have the potential to improve AIVs' availability to rural and urban populations throughout the year. The aim of this study was to determine the content of selected minerals (Ca, Fe, K, Mg, Na, P, Zn) and secondary plant metabolites (glucosinolates, carotenoids, flavonoids and phenolic acids) of five selected AIVs commonly consumed in Tanzania: amaranth (*Amaranth* spp.), Chinese cabbage (*Brassica chinensis*), pumpkin leaves (*Cucurbita maxima*), Abyssinian mustard (*B. carinata*) and black nightshade (*Solanum nigrum*). To determine the actual state of profiles of the selected micronutrients and secondary plant metabolites in leaf material of the AIVs available in Tanzania, plant samples from two different markets were subjected to analytical component analyses at Humboldt-Universität zu Berlin. Mineral contents were determined by using inductively coupled plasma-optical emission spectrometry (ICP-OES). Secondary plant metabolites were specifically extracted and quantified via high-performance liquid chromatography (HPLC). Metabolites were identified on the basis of mass fragmentation (mass spectrometry), as well as retention times and specific UV-spectra if commercial standards were available. Results indicated significant differences in the con-

Contact Address: James Simon Chacha, Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Lentzeallee 55, 14195 Berlin, Germany, e-mail: james.simon.chacha@hu-berlin.de

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tents and compositions of the specific minerals as well as glucosinolates, carotenoids, flavonoids and phenolic acids in the different AIV samples. In conclusion, the selected and analysed AIVs have the potential to improve local food environments by providing health-promoting secondary plant metabolites and micronutrients for improved diets in rural and urban Tanzania.

Keywords: African indigenous vegetable, carotenoids, flavonoids, food environments, glucosinolates, micronutrients, phenolic acids

The relative role of soil, climate, and genotype in the variation in nutritional value of *Annona senegalensis* fruits and leaves

Janine Conforte Fifonssi Donhouede[1], Valère Salako[2], Achille Ephrem Assogbadjo[3], Ana IF Ribeiro Barros[4], Natasha Ribeiro[1]

[1]*Eduardo Mondlane University, Dept. of Forest Engineering, Mozambique*

[2]*University of Abomey-Calavi, Lab. of Biomathematics and Forest Estimations, Benin*

[3]*University of Abomey Calavi, Lab. of Applied Ecology, Benin*

[4]*University of Lisbon, Forest Research Center (CEF), Portugal*

Annona senegalensis Pers is a multipurpose tree species valued for food and medicinal uses of its leaves and fruits in Africa. As a traditional food plant in Africa, *A. senegalensis* plays an important role in the context of food security, and its domestication has the potential to improve nutrition, foster development, and support sustainable land use. Although there have been attempts to document the proximate composition of its fruits and leaves, little is known about the relative role of soil, climate, and genotype on the nutritional quality. The present study evaluated the variation of the proximate composition in its fruits and leaves in populations from Benin and Mozambique. It further assessed the impact of soil, climate and genotype on the proximate composition. Data were collected from four populations genetically different and analysed using descriptive statistics, analysis of variance (ANOVA), principal component analysis and redundancy analysis (RDA). Results revealed significant variation in the proximate composition of the fruits and the leaves between the studied populations. Moisture and lipids were respectively six times and 1.27 times higher in the fruits than in the leaves, while ashes, fibers and proteins were approximately twice higher in the leaves than in the fruits. Genetic groups, climate and soils were found to influence this variation. Soil (47.56 %) and genotype (38.87 %) better explained the variability in the proximate composition of the fruits and the leaves than climate (13.56 %). Our study provides essential information that could be harnessed in the domestication and breeding programme of *A. senegalensis* for its edible parts.

Keywords: *Annona senegalensis*, proximate composition, macronutrients, variability

Contact Address: Janine Conforte Fifonssi Donhouede, Eduardo Mondlane University, Dept. of Forest Engineering, Maputo, Mozambique, e-mail: jdonhouede@gmail.com

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Fresh strawberry (*Frageria × ananassa*) and jamun (*Syzigium cumini*) fruit physico-chemical, antioxidative and organoleptic quality management by organic acid application

Sami Ullah, Kashif Razzaq, Ishtiaq Ahmad Rajwana, Hafiz Nazar Faried, Gulzar Akhtar, Ambreen Naz, Rafique Farzana, Rasheeqa Tariq, Um E Habiba

MNS-University of Agriculture, Dept. of Horticulture, Pakistan

Fresh fruits contribute significantly to global nutritional security. However, fresh horticultural produce especially fruit is highly perishable and the global postharvest losses account for 30 to 40 %. The reduction in postharvest losses can appreciably contribute to food and nutritional security for the growing world population. Quinic acid (QA) and oxalic acid (OA) are natural organic acids found in plants. However, the pre-harvest and postharvest treatment of QA and OA are limited in fresh fruit and warrants further investigation. Keeping in view the benefits of these acids, an integrated study was executed to explore the pre-harvest and postharvest application of QA and OA on strawberry (*Frageria × ananassa* cv. Chandler) and jamun (*Syzigum cumini* cv. Desi) fruit physico-chemical, antioxidative and organoleptic attributes at shelf. The study comprised of three independent experiments, experiment-I & -II investigated pre-harvest and postharvest OA-application (0, 0.5, 1 and 2 mM) on jamun fruit quality, while experiment-III examined postharvest application of QA (0, 0.25, 0.5 and 1 mM) on strawberry fruit quality. All the treated fruit were kept at ambient conditions (25± 2 °C and 60–65 % RH) and were investigated for physico-chemical, antioxidative and organoleptic quality attributes on daily basis. The results reveled that application of higher OA dose (both as pre-harvesr and postharvest treatment) significantly decreased the jamun fruit physical losses [weight loss, fruit skin colour L, a, b, skin shriveling and disease occurrence and respiration rate], significant higher biochemical [total soluble solid (TSS), titratable acidity (TA) and vitamin C] and antioxidative parameters [total antioxidants, total phenolic contents (TPC), anthocyanin, activity of superoxide dismutase (SOD) enzyme] as compared to untreated fruit at shelf. Similarly, 1 mM-QA strawberry fruit exhibited significantly lower fruit weight loss, ethylene production, respiration rate, and higher fruit firmness, juice pH, anthocyanin contents, vitamin C, total antioxidant, TPC and SOD enzyme activity as compared to untreated fruit. Resultantly, pre-harvest and postharvest treatment of both OA and QA significantly retained the postharvest quality of fresh strawberry and jamun fruit at ambient conditions.

Keywords: Organoleptic attributes, physiological quality

Microbiota and metabolites in the spontaneous fermentation of agricultural products in the Ecuadorian Amazon

Roldán Torres-Gutiérrez[1], Sebastian Mateo Valencia Ramos[1], Evelyn Andrea Oña Lugmaña[1], Bettina Eichler-Löbermann[2]

[1]*Regional Amazon University Ikiam, Live Science Faculty, Ecuador*
[2]*University of Rostock, Agricultural and Environmental Faculty, Germany*

The transformation of agricultural products into inputs with added value is one of the main challenges of modern agriculture. The fermentation of agricultural waste carried out by indigenous microorganisms is one of the pathways to close production cycles with the desired added value while conserving the environment. The fermentation process is an option for the utilisation and environmental management of residues generated by the commercialisation of agricultural products and can be used to produce photochemicals, structural polymers, and bioactive compounds. Organic residues, specifically agricultural and forestry wastes, have the potential to be raw materials for the creation of third-generation biofuels, in addition to being used for the creation of biofertilisers, biomaterials, and bioremediation, among others. Therefore, the objectives of this research were (i) to characterise the inoculum obtained from residues generated by the commercialisation of agricultural products in the city of Tena, (ii) to identify the morphology of the microorganisms present in the ferment and (iii) to identify the volatile compounds resulting from the semi-solid fermentation of the primary inoculum. The results showed that 68 % of the surveyed premises discard 1 to 3 kg of waste per day, including cereals, roots, tubers, oilseed plants, fruits, and vegetables, from which the inoculum for the fermentation process was obtained. Yeasts were the predominant microbial group in the ferment with 2.6E+06 CFU mL^{-1}. The isolated fungi presented morphologies typical of the genera *Fusarium*, *Geotrichum*, *Acremonium*, and *Scopulariopsis*. For bacteria, the most frequent morphology was bacilli. In the liquid phase of the ferment, 20 volatile compounds were identified, including lactic acid, butyrolactone, and 1,3-propanediol. These results demonstrate the potential of fermentations of agricultural residues in local markets for obtaining compounds of biotechnological interest.

Keywords: Bioproducts, fermentation, isolates, microorganisms, waste

Contact Address: Roldán Torres-Gutiérrez, Regional Amazon University Ikiam, Live Science Faculty, Parroquia Muyuna Kilómetro 7 Vía a Alto Tena, 150150 Tena, Ecuador, e-mail: roldan.torres@ikiam.edu.ec

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Nutritional and anti-nutritional composition of some wild edible plants consumed in southwest Ethiopia

Abebe Yimer[1], Sirawdink Fikreyesus Forsido[1], Getachew Addis[2], Abebe Ayelign[3]

[1]*Jimma University, College of Agriculture and Veterinary Medicine, Dept. of Post-Harvest Management, Ethiopia*

[2]*Ethiopian Public Health Institute, Ethiopia*

[3]*Addis Ababa University, Center for Food Science and Nutrition, Ethiopia*

The Meinit community utilised wild edible plants (WEPs) widely for a variety of purposes mainly as food, household healthcare, and market value. WEPs namely, Chaw (*Solanum nigrum* L.), shutamodoroy (*Vigna membranacea* A. Rich), Entut (*Dioscorea praehensilis* Benth.), Gagut (*Trilepisium madagascariense* D.C.), and Tikawoch (*Cleome gynandra* L.), are naturally grown and consumed by Meinit cultural community in Bench Maji Zone, southwest Ethiopia. However, the proximate, mineral, and anti-nutritional compositions of these WEPs were not evaluated. This study aims to evaluate the proximate, mineral, and ant-nutritional contents of five WEPs. The WEPs were randomly collected from natural habitats and pooled samples were made. The nutritional and anti-nutritional composition of these WEPs were analysed following standard food analysis methods. Nutritional analysis reveals that the WEPs had important nutrients in the ranges of protein (4.00 to 21.66 %), fat (0.67 to 6.14 %), fiber (10.06 to 22.28 %), carbohydrate (38.11 to 82.99 %), and energy (274.99 to 371.05 kcal/100 g). Moreover, these WEPs contained substantial values of macro and micro minerals such as calcium (3.69 to 594.78 mg/100 g), potassium (440.61 to 1487.80 mg/10 0g), sodium (174.87 to 277.42 mg/100 g), magnesium (68.19 to 588.06 mg/100 g), iron (0.83 to 38.46 mg/100 g), zinc (2.41 to 5.94 mg/100 g), and copper (0.06 to 0.49 mg/100 g). The anti-nutritional composition of five WEPs ranged from phytate (8.60 to 307.33 mg/100 g, condensed tannin (5.76 to 328.96 mg/100 g), and oxalate (43.68 to 443.87 mg/100 g). These results demonstrate that these WEPs had a significant source of food nutrients that contribute to dietary diversification, and food and nutrition security in rural people of southwest Ethiopia and elsewhere in the tropical country. Additionally, these research outputs provide baseline information for the food industry, policymakers, and community nutrition.

Keywords: Anti-nutritional content, nutrient composition, wild edible plants

Contact Address: Abebe Yimer, Jimma University, College of Agriculture and Veterinary Medicine, Dept. of Post-Harvest Management, Jimma, Ethiopia, e-mail: abebeyimer2010@gmail.com

Rice milling and parboiling trade-offs for economic and nutritional gains in West Africa

Sali Ndindeng[1], Erasmus Tang[2], Edgar Twine[1], Victor Taleon[3]

[1]*Africa Rice Center (AfricaRice), Agri-food Systems, Crop Based System, Farming Systems and Post-harvest, Côte d'Ivoire*
[2]*Institute of Agricultural Research for Development, Food Science, Cameroon*
[3]*HarvestPlus, United States*

Rice is a major source of nutrients, largely contributing to the food and nutrition security of millions of people in West Africa. The role of rice in the diets of West Africans is projected to keep increasing with the triple influence of urbanisation, consumer preference and demographic growth. Rice's inherent properties and its suitability for the preparation of local dishes (specific culinary suitability) are affected by processing methods, which influence consumer acceptance and market price. To respond to consumer preferences and hence attract premium prices, rice processing commits to quality upgrading, but may compromise grain nutrient content – generally a credence attribute. Although consumers generally manifest heterogeneity in rice preferences, empirical evidence points to a few attributes guiding the choices that commonly define the premiums. Hedonic pricing models have steadily shown that consumers are willing to pay price premiums for head rice, rice that cooks fast, slender grains, low-intermediate amylose, parboiled rice, and rice with high swelling capacity. But they strongly discount rice that is chalky, high in amylose and with impurities. Higher milling degree increases grain crystallinity, slenderness, and lightness, while decreasing milling returns, head rice, proteins, lipids, micronutrient, phytate and arsenic contents. Rice parboiling increases milling returns, head rice, water soluble vitamins, Fe and arsenic content, and reduces crystallinity, starch digestibility, lipid, phytic acid and Zn content. Information on the optimum milling and parboiling regimes that provide both economic and nutritional gains to society is scanty in the literature and is organised in a way that does not easily inform technological and policy changes. If milling is not extensive, parboiling appears to provide a better economic and nutritional trade-off. However, the process consumes water, energy, time and generates GHG emissions, which can be mitigated when improved parboiling equipment and methods are used.

Keywords: Economic returns, milling degree, nutritional returns, parboiling

Contact Address: Sali Ndindeng, Africa Rice Center (AfricaRice), Agri-food Systems, Crop based system, Farming systems and Post-harvest, Africa Rice Center, M'be Research Station, Bouake, Côte d'Ivoire, e-mail: s.ndindeng@cgiar.org

A gentle push towards behaviour change: Designing nudge interventions to increase hygiene and food safety at pork joints in Uganda

Kristina Roesel[1], Steven Kakooza[2], Denis Mugizi[1], Joshua Waiswa[2], Velma Kivali[3], James Bugeza[3], Lillian Diaz[4], Elizabeth Cook[1]

[1]*International Livestock Research Institute (ILRI), Animal and Human Health, Kenya*
[2]*Vétérinaires sans Frontières Germany, Uganda*
[3]*International Livestock Research Institute (ILRI), Animal and Human Health, Uganda*
[4]*17 Triggers, Cambodia*

Most of the perishable food in low- and middle-income countries is sold in informal markets where food handlers are not usually trained in good hygienic practices. There are different approaches to improve food safety in those markets, some of which include capacity building. However, one-off trainings are not usually sustainable as behaviours are deeply rooted and often lead to unconscious practices that can increase risk of food contamination. Close follow-up is intense in terms of human and financial resources. Nudges have been described to influence behaviour with varying results, partly depending on whether they have been imposed on or co-created with the end-users. In this study we describe the human-centred-design process from identifying critical control points between slaughter and retail to co-creating nudges that could potentially lead to better compliance of meat handlers in Uganda with good hygienic practices. Three of the WHO "Five Keys To Safer Food" were selected as the target behaviours to improve. The qualitative research was implemented in the greater Kampala area between October 2020 to December 2021 and involved 119 meat handlers, pork joint customers, food safety and veterinary technical experts and over 20 project stakeholders. Findings from the initial 'explore' phase generated a number of insights on meat handlers' perceptions and attitudes that were later used to generate ideas and solutions in co-creating nudges during the 'experiment' phase: 1) Meat handlers eat the pork they handle at work and have low risk perception; 2) Meat handlers feel their practices are acceptable; 3) Meat handlers see 'broken windows' which set the norm for unhygienic behaviour; 4) Meat handlers follow the path of least resistance; 5) Meat handlers keep up appearances for customers; and 6) Owners want to see returns on hygienic investments. Forty-two early prototypes were co-created with potential end users and after several iterations, two nudge kits emerged, e.g. the "Keep Clean Loop" and the "Tricolour Kitchen". In a subsequent pilot test we assessed if the nudges help reducing the burden of foodborne pathogens and if behaviour of meat handlers changes sustainably.

Keywords: Behaviour, food safety, hygiene, meat handler, pork, Uganda

Contact Address: Kristina Roesel, International Livestock Research Institute (ILRI), Animal and Human Health, PO Box 30709, Nairobi, Kenya, e-mail: k.roesel@cgiar.org

Nutritional enhancement of Kenyan porridges: Chia seed and oyster mushroom fortification

Alice Ndunge Charles[1], Susan Chemutai[1], Sendeku Takele Alemenh[2], Monica Mburu[1], Daniel Njoroge[1], Viktoria Zettel[2]

[1]*Dedan Kimathi University of Technology, Inst. of Food Bioresources Technology, Kenya*
[2]*University of Hohenheim, Process Analytics and Cereal Science, Germany*

The CHIAM project is an ambitious initiative that seeks to develop a climate-smart solution for sustainable food systems in Africa, addressing the complex challenges presented by the Food Systems and Climate (FOSC) call. To achieve this, the project emphasises the introduction of innovative agricultural technologies and the comprehensive redesign of the existing African agri-food value chain. This approach is aimed at substantially increasing resilience, sustainability, and circularity in the region's food systems. A key component is the implementation of a chia-mushroom-pig biogas value chain, which plays a crucial role in diversifying and strengthening the resilience of African food systems in the face of climate change impacts. In collaboration with the main CHIAM project, the project partner in Germany is working on fortifying local staple foods with chia seeds and oyster mushrooms, with an aim of providing essential nutrients to the local communities. To assess the potential benefits of this fortification, traditional Kenyan porridges made from white maize, sorghum, and pearl millet are being examined for improvements in nutritional quality and technological effects. Researchers are employing various analytical tools, such as the Rapid Visco Analyzer (RVA), rheological measurements, and texture profile analysis, to determine the impacts of the cereal substitution on the porridges. Porridge recipes consist of one part maize, sorghum, or pearl millet flour, combined with two or four-fifths parts water, resulting in thick or thin porridge, respectively. Substitution levels of 3 %, 6 %, and 9 % of the cereals are being tested with ground chia seeds or oyster mushrooms, as well as combinations for thick porridge. Preliminary findings indicate that when maize flour is replaced with increasing amounts of oyster mushrooms, the peak viscosity, as measured by RVA, is reduced. In contrast, incorporating higher amounts of chia seeds into the porridge recipes results in increased viscosity and strength, even though the values remain below standard levels. These observations suggest that a higher chia seed content leads to an increased water-binding capacity within the porridge, potentially improving its overall quality. More experiments are currently ongoing, and more comprehensive results will be presented at the upcoming conference.

Keywords: Chia, nutritional enhancement, oyster mushroom, porridge

Contact Address: Viktoria Zettel, University of Hohenheim, Process Analytics and Cereal Science, Institute of Food Science and Biotechnology, Garbenstr. 23, 70599 Stuttgart, Germany, e-mail: Viktoria.Zettel@uni-hohenheim.de

Empowering sustainable shea butter processing: A decentralised energy access solution for Burkina Faso

Bignon Stephanie Nounagnon[1], Sebastian Romuli[2],
Yrébégnan Moussa Soro[1], Joachim Müller[2]

[1]*International Inst. for Water and Environmental Engineering, Lab. for Renewable Energies and Energy Efficiency, Burkina Faso*
[2]*University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany*

Shea (*Vitellaria paradoxa*), a native sub-Sahara African tree growing in dry-savannah regions is highly valued by the cosmetic, pharmaceutical, and food industries worldwide. However, due to inaccessibility to processing resources namely electricity and water, shea kernels grown in rural areas are exported to urban regions or abroad at extremely low prices. The shea kernels are there proceeded into highly-valued products i.e. shea butter and other refined sub-products. This study intends to design a sustainable and decentralised energy access-based solution for shea butter processing chain in rural regions. Considering current energy access portfolio trends in sub-Saharan Africa, solar photovoltaic has been targeted as the principal power technology. Shea butter extraction experiments were conducted under local conditions at an oil milling company in Toussiana, Burkina Faso. The electrical powering system was designed and sized using Homer Energy Pro software considering the connection of both the total loads and only critical loads of the processing facility. Sensitivity analysis was carried out based on the overall targeted shea butter production and unused excess electricity generated during off-processing periods of the year. Preliminary results show that a solar photovoltaic power system is effective for shea butter processing when production operations are carried out continuously throughout the year and during daytime. In addition, monitoring the efficiency of the appliances highlighted that up to 40 % of the required energy is saved by switching to efficient electrical motors and upgrading the wiring system. The research perspectives include cost-benefit analysis as well as supply and demand side monitoring to ensure power quality aspects to meet the IEEE 519–2014 standards.

Keywords: Economic feasibility, energy access, energy efficiency, shea butter

Contact Address: Bignon Stephanie Nounagnon, International Inst. for Water and Environmental Engineering, Lab. for Renewable Energies and Energy Efficiency, Rue de la science, 01 BP 194 Ouagadougou, Burkina Faso, e-mail: stephanie.nounagnon@2ie-edu.org

Food and nutrition security

Food system diversification for food security

Online posters

Pathways to nutritional outcomes for different irrigation arrangements: Evidence from smallholder households in rural Kenya

Nixon Murathi Kiratu[1], Eefje Aarnoudse[2], Martin Petrick[1]

[1]Justus-Liebig University Giessen, Inst. of Agricultural Policy and Market Research, Germany

[2]Bonn-Rhein-Sieg University of Applied Sciences, Intern. Centre for Sust. Dev., Germany

Irrigation is considered a viable approach to improve household nutrition as well as galvanize local and regional food systems against vagaries such as climatic change. However, the pathways through which nutritional outcomes of smallholder households involved in different ways of irrigating are understudied and scantly documented. Though the suggested pathways of achieving nutrition through irrigation are production, income, water sanitation and hygiene and women's empowerment, the linkages to nutritional outcomes are not understood well and often, nutritional measurement approaches neglect the households' most vulnerable members; women and children. Moreover, the existing scarce literature analyses these pathways handling irrigation as a uniform agricultural input. This study took the standpoint that irrigation is diverse and different irrigation arrangements (i.e. socio-technical set-up in which irrigation takes place) affect household nutritional outcomes through different pathways. Data from irrigating farm households in the public irrigation scheme and farmer led irrigation arrangements were used in this study from a cross-sectional household survey data from Kenya. Results from irrigation as an aggregated input variable are also given for clarity and comparison purposes. The results are from a simultaneous equation model that was employed to investigate pathways through which irrigation and different irrigation arrangements attain household nutritional outcomes sensitive to women and children. The results showed that the different irrigation arrangements have different nutrition-outcome pathways. The results revealed that overall irrigation affects production diversity, farm income and women empowerment and nutrition-outcomes were improved through production diversity and income pathways. The farm households in the public irrigation scheme arrangements attained better nutritional outcomes through the production diversity pathway even though this irrigation arrangement positively affects production diversity, income and women empowerment. The farmer-led irrigation arrangement was found to positively affect farm income and women empowerment and these two pathways were found to lead to

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Contact Address: Nixon Murathi Kiratu, Justus-Liebig University Giessen, Inst. of Agricultural Policy and Market Research, Unterhof 69-1006, 35392 Giessen, Germany, e-mail: nixonstudy@gmail.com

improved household nutritional outcomes. This study provides plausible evidence that different irrigation set-ups have diverse irrigation-nutrition impact pathway as well as different impact on nutritional outcomes. Consequently, there is need for specific policy interventions based on irrigation arrangements as opposed to a unilateral policy encompassing irrigation.

Keywords: Irrigation-arrangements, Kenya, nutrition, pathways, simultaneous-equation-model, smallholder-households, women empowerment

Food system transformation for sustainable food and nutrition security for all: What place for smallholder tree-crop farming?

Martha Ataa-Asantewaa[1], Mirjam Ros-Tonen[1],
Bart de Steenhuijsen Piters[2], Joyeeta Gupta[1]

[1]*University of Amsterdam, Dept. of Geography, Planning and International Development Studies, Amsterdam Inst. for Social Science Research, The Netherlands*
[2]*Wageningen University, Wageningen Economic Research, International Policy Subdivision, The Netherlands*

Food system transformation has become ever more critical in the wake of the impacts of climate change and the COVID-19 pandemic to ensure food and nutrition security for all in a sustainable manner. Much attention goes to smallholder agriculture and food production, which provide 50–70 % of global food production. However, much less is known about how a growing focus on high-value tree crops that link farmers to global value chains affects farming households' food and nutrition security. This paper aims to analyse these implications for Ghanaian tree-crop farming households who engage in cocoa and oil palm value chains. We use a mixed-method approach, including surveys, and interviews to analyse food availability, access, utilisation, and stability, and critical dimensions of food sovereignty, such as autonomy and the sustainability of production. We found that most households depend on their food production. However, total household food and nutrition security depends on the household's income capacity and own food production. While engagement in tree-crop production assures some income capacity, the required income capacity is only met by households that engage in multiple tree crops, while most single tree-crop and landless households face seasonal food insecurity due to their low incomes. Dietary diversity was similar amongst all household types proving that high-income capacity does not automatically lead to better nutrition as households spend money on other things or non-nutritious foods. Food and nutrition security was better among cocoa-farming households than oil palm households proving the importance of having the autonomy to intercrop food and tree crops in the wake of declining food-crop lands due to tree-crop expansion. While cocoa farmers have the autonomy to intercrop, oil palm farmers lose that autonomy, particularly when engaged in outgrower schemes. The sustainability of smallholder food-crop production depends on intercropping, but the overuse of agrochemicals like weedicides remains a major threat to sustainable food production. The findings reveal critical entry points to a just food system transformation that ensures sustainable food and nutrition security for all and highlights the importance of considering heterogeneity among smallholders and their production context as a starting point for equitable food system transformation.

Keywords: Cocoa, Ghana, household food and nutrition security

Contact Address: Martha Ataa-Asantewaa, University of Amsterdam, Dept. of Geography, Planning and International Development Studies, Amsterdam Institute for Social Science Research, Goethelaan 46, 3533 VS Utrecht, The Netherlands, e-mail: m.ataa-asantewaa@uva.nl

The potential of mushroom production for food security and farmer incomes in Uganda

Daniel Grimm, Enno Sonntag

Thuenen Institute of Organic Farming, Germany

It is common practice for smallholder farmers in Uganda to burn maize straw on the field after harvest. This quickly clears the fields for ploughing and sowing but it pollutes the air and reduces the carbon content and fertility of soils over time. Instead, maize crop residues can be used as a substrate for oyster mushroom cultivation following a low-tech procedure. Oyster mushrooms are an esteemed food in Uganda and their production can increase the amount of food, especially protein, produced per hectare, thus contributing to food security. The revenue from selling oyster mushrooms can furthermore help to diversify farmer incomes. To assess the potential of this idea, we carried out a case study in Kibale, Uganda. We first quantified maize yields and the amount of crop residues on different fields over two seasons and interviewed the respective farmers regarding agricultural practices. We took samples of maize grains and crop residues and analysed them for proximate composition, carbon and nitrogen content. Then, we cultivated oyster mushrooms on the crop residues to assess their production potential. We show how much of the maize crop residues can be converted into edible mushrooms and spent mushroom substrate, which can be used as an organic fertiliser. Finally, we interviewed mushroom farmers in and around Kampala, to learn about the state and constraints of local production technology markets and identified substrate availability as a key challenge. We combine fieldwork, experimental data and interviews, to show that there is a considerable potential for producing oyster mushrooms on maize crop residues in Uganda. Furthermore, we discuss obstacles to adoption of this approach and potential environmental pitfalls.

Keywords: Circular enonomy, food security, mushrooms, recycling, smallholder farming, soil fertility

Impacts of social capital and rural households' livelihood strategies on food/nutrition security and income

Gari Duguma[1], Fekadu Beyene[1], Kebede Duga[2]

[1]*Haramaya University, Agricultural Economics and Agri Business, Ethiopia*
[2]*Keam Business and Development Consultants Plc, Management and Programme Operations, Ethiopia*

Food demand worldwide is always rising, hence increasing smallholder farmers' productivity and production through appropriate livelihood methods in order to address the issue is essential. As the most important resources for livelihoods, social capital has effects on rural household's livelihood strategies. The food system of rural households, which are typically impacted by climatic and non-climatic shocks, is influenced by both the state of social capital and household livelihood strategies. Food security is impacted by social capital by enhancing the pillars of food security (food availability, food accessibility, food consumption, and food system stability). The household's participation in local organisations leads to the exchange of food goods and information, which makes food more readily available and accessible. The degree of social capital, like Ethiopia, has a significant impact on rural households' access to food and nutrition as well as income level. Data was collected from 400 randomly selected households in 2023 from North Showa, Ethiopia. The results of a multinomial endogenous switching model show that participation in farming and non-farming livelihood strategies increases farm households' food and nutrition security status by 25 %, while participation in farming and off-farming livelihood diversification strategies and farming with both non-farming and off-farming livelihood diversification strategies increases households' food and nutrition security by 43 and 37 %, respectively, over non-diversified households. The sample households' high and very high levels of local organisation engagement improve the food security status of farm households by 33 and 38 % in comparison to low level participant households, respectively (statistically significant at the 1 % probability level). The impact evaluation of mean comparison results demonstrates that very high level participation in the local social organisation boosts farm households' livelihood diversification techniques by 40 % compared to low participant households. Similarly, having high levels of social trust in the community increases farm households' livelihood diversification strategies by 59 % over low-trust households. Thus, the findings of this study are predicted to offer a substantial contribution as policy and strategic inputs in establishing rural livelihood improvement programmes, besides stallholder farmers' improvement of their food/nutrition security, income and quality of life and food systems improvement in rural areas.

Keywords: Endogenous switching model, Ethiopia, food/nutrition security, livelihood strategies, social capital

Contact Address: Gari Duguma, Haramaya University, Agricultural Economics and Agri Business, Bole, 1000-250 Addis Ababa, Ethiopia, e-mail: lidconsult@yahoo.com

Impacts of biofortified bean adoption on productivity, income, and nutritional outcome: The case of Zimbabwe

RICHARD ALIOMA[1], BHO MUDYAHOTO[2]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*International Food Policy Research Institute (IFPRI), Zimbabwe*

Enhancing agricultural productivity by adopting proven technologies presents a credible pathway to economic development and micronutrient deficiency reduction. Adopting improved biofortified beans has the potential to contribute to economic development and micronutrient reduction. Few studies provide evidence of the linkage between adopting iron beans, income, and nutritional outcomes. The study assessed the impact of iron bean adoption on bean yield, agricultural income and disability life-adjusted years saved. The study uses nationally representative cross-sectional data collected from 1517 respondents across seven provinces in Zimbabwe. First, we use the triple hurdle that integrates awareness, planting, and area allocation decisions to estimate the determinants of biofortified bean variety adoption. Secondly, we estimate the effect of adopting iron beans on yield and income using endogenous switching regression, which addresses the endogeneity challenges. Lastly, we estimated the disability life years saved due to the adoption of biofortified beans. The results indicated that 56 % of the respondents know biofortified beans, and 28 % planted iron beans in 2022. The descriptive has shown that adopters of iron beans are older, have larger family sizes, smaller farm sizes, and are more likely to irrigate their bean plots. Adopters use more bean seeds and are less likely to use herbicides. The econometric results indicated that land owned, the household head's age, education level, and bicycle ownership determine awareness of iron beans. The determinants of planting iron bean variety are household size, education of the household head and owning a mobile phone. The source of seed, fertiliser application and irrigation of the bean plot influenced the area under iron beans. The adoption of iron beans did not increase the bean yield of the adopters; however, it had a positive and significant effect on agricultural incomes. The reduction of the total disease burden through adopting iron beans was 1.3 %. Overall increasing access to seed of iron beans would make households earn more incomes, and consumption of iron beans would contribute to the reduction of disease. It is essential to understand the mechanism through which the adoption of iron beans leads to increased incomes since there were no yield differences.

Keywords: Biofortified beans, nutritional outcomes, technology adoption, Zimbabwe

Contact Address: Richard Alioma, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Wollgrasweg 43, Stuttgart, Germany, e-mail: richard.alioma@uni-hohenheim.de

Combating malnutrition in Africa through diversification of the food systems

Emmanuel Donkor[1], Michael Frei[1], Sali Ndindeng[2], Dominique Van Der Straeten[3], Christophe Matthys[4], Alisdair Fernie[5], Tiziana de-Magistris[6], Patrick Teixeira[7], Chiji Ojukwu[8], P. C. Sibiry Traoré[9], Rousseau Djouaka[10], Sharon Chacha[11], Mube K. Hervé[12], Paul Z. Diby[13], Ina Danquah[14], Rodrigue Kamga[15], Irmgard Jordan[16], Kassi Elia[17], Benedikte Grenov[18], Juliana Kiio[19], Haris I. Parvez[20], Tsanko Gechev[21]

[1]Justus Liebig University Giessen, Inst. of Agronomy and Plant Breeding, Germany
[2]Africa Rice Center (AfricaRice), Agri-food Systems, Crop Based System, Farming Systems and Post-harvest, Côte d'Ivoire
[3]Ghent University, Laboratory of Functional Plant Biology, Department of Biology, Belgium
[4]University Hospitals Leuven, Dept. of Chronic Diseases and Metabolism & Department of Endocrinology, Belgium
[5]Max-Planck-Institute of Molecular Plant Physiology, Germany
[6]Agrifood Research and Technology Centre of Aragón (CITA), Spain
[7]World Food Programme, Regional Centre of Excellence against Hunger and Malnutrition, Côte d'Ivoire
[8]Africa Projects Development Centre, Nigeria
[9]Manobi Africa, Mauritius
[10]International Institute of Tropical Agriculture, Benin
[11]Food Security for Peace and Nutrition-Africa, Kenya
[12]University of Dschang, Faculty of Agriculture and Agricultural Sciences, Cameroon
[13]Entreprise en Sante et Securite au Travail, Côte d'Ivoire
[14]Heidelberg Universitätsklinikum, Heidelberg Institute of Global Health, Germany
[15]Agribusiness Vocational Training Centre, Cameroon
[16]The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya
[17]Opportunities Industrialisations Center International Côte d'Ivoire, Côte d'Ivoire
[18]University of Copenhagen, Dept. of Nutrition, Exercise, and Sports, Denmark
[19]Kenyatta University, Dept. of Food, Nutrition and Dietetics, Kenya
[20]De Montfort University, Leicester School of Allied Health Sciences, Fac. of Health and Life Sciences, United Kingdom
[21]Center of Plant Systems Biology, Bulgaria

Africa faces persistent undernutrition, micronutrient deficiencies and growing rates of overweight, obesity, and diet related diseases known as the triple burden of malnutrition. These nutritional problems not only overburden health care system but also undermine economic growth and development in Africa.

Contact Address: Emmanuel Donkor, Justus Liebig University Giessen, Dept. of Agronomy and Crop Physiology, Inst. for Agronomy and Plant Breeding, Heinrich-Buff-Ring 26-32, 35392 Giessen, Germany, e-mail: emmanuel.donkor@agrar.uni-giessen.de

ID 409

HealthyDiets4Africa is a transdisciplinary project with partners from 12 African and nine European countries that aims to harness the potential of food systems diversification to address malnutrition and improve food and nutrition security in Africa. Our central hypothesis is that diversifying different elements of the food chain will improve nutritional health and reduce malnutrition in Africa, while achieving economic and environmental benefits. Our overall goal is to build sustainable food systems through diversification in Ivory Coast, Benin, Ghana, Liberia, Nigeria, Cameroon, Uganda, and Kenya. Diversification can occur at different stages of the food value chain, including production, supply chains, and consumption, and at various levels of organisation, ranging from the farm to scaling at the continental level. The project will engage the different food value chain players, policy makers and key partners and apply interdisciplinary methodology to actualize the project goals. To achieve the overall goal, the project is organised into four clusters. Cluster 1 includes mapping and monitoring of dietary diversity and evaluating determinants of dietary diversity within the food environment. Cluster 2 involves assessing nutrient diversity in traditional, underutilised, and novel foods and diversifying agricultural production and food processing. Cluster 3 entails co-designing and assessing economic acceptability of diversified diets and novel food products, enhancing food safety through dietary diversification, and evaluating impacts of diversification on health outcomes. Cluster 4 involves the establishment of scaling infrastructure to promote adoption of approaches towards diversified food systems and enabling better policy environment and strengthening stakeholders' capacities on all relevant levels to promote informed decision-making processes. In line with the objectives of the EU Green Deal and the global elements of the EU Farm-to-Fork Strategy, HealthyDiets4Africa aims to contribute to the transformation of food systems in Africa through diversification to make them more resilient, sustainable, and climate-friendly, while improving the supply of safe, nutritious, and affordable food to combat malnutrition.

Keywords: Diversification, food and nutrition security, food systems, food value chains, innovations, interdisciplinary methodology, Sub-Saharan Africa, sustainable diets

From waste to relief: Unlocking the potential for food rescue in low- and middle-income countries

Susanne Bodach, Aruni Narmada Athukorala,
Hasintha Wickramaarachchi

International Water Management Institute (IWMI), Sri Lanka

Food rescue has emerged as a promising approach to address the interrelated issues of food insecurity and food waste. According to the food waste hierarchy, the next best strategy after food waste prevention is to donate surplus food for human consumption. However, while some countries have well-established networks of charities and government support to promote surplus food donation, food rescue in most developing countries is often less structured and smaller in scale.

To gain insights into the current landscape of food rescue, this study thoroughly examined existing food rescue operations and systems, mainly from the UK, Singapore, Malaysia, India, and the Philippines. The study also analysed several countries' food rescue policy environments to understand how an enabling environment can be created. A particular focus was set on food safety being a critical consideration when rescuing and donating surplus food. Simplified food safety guidelines, staff training, and adequate storage and transportation facilities are crucial to food safety.

Effective partnerships between food rescue organisations, food businesses, government agencies, and other stakeholders are also critical to the success of food rescue efforts. The study found a need to develop such partnerships in developing countries, where they may be less established than in the Global North.

To facilitate the development of an enabling environment for food rescue in low- and middle-income countries (LMICs), the study developed a set of templates, including relevant food safety guidelines, partnership contracts, and policy templates. These resources can serve as valuable tools for stakeholders in LMICs to promote and enhance food rescue efforts.

In conclusion, this presentation will provide essential insights into the current landscape of food rescue, including key challenges and opportunities for improvement. By examining existing policies, partnership frameworks, and food safety challenges, this study offers a roadmap for stakeholders to promote food rescue that can help address food insecurity and food waste.

Keywords: Circular economy, food rescue, food security, food waste, food waste prevention, food waste redistribution, partnerships, surplus food donation, waste reduction

Contact Address: Susanne Bodach, International Water Management Institute (IWMI), 127 Sunil Mawatha Pelawatte, 10120 Battaramulla, Sri Lanka, e-mail: s.bodach@cgiar.org

Kitchen gardens reduce time needed to access vegetables: A qualitative study in Turkana, Kenya

Irmgard Jordan[1], Beatriz Herera[2], Francis Oduor[1], Yuko Muramatsu[2], Maria Gerster-Bentaya[2], Andrea Knierim[2], Céline Termote[1]

[1]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya*
[2]*University of Hohenheim, Inst. of Social Science in Agriculture, Chair of Communication and Adivisory Services in Rural Areas, Germany*

The food environment is the context in which people select, acquire, prepare, and consume food and is thus a determinant of diet quality and nutritional outcomes as people mainly consume what is within their physical and economic reach. Findings from a food environment assessment showed limited options to select and acquire vegetables and fruits and low dietary diversity at household level. Ten randomly selected Community Units in Turkana (semi-arid/arid) were invited to co-create community action plans to enhance access to vegetables. Most communities established kitchen gardens. Ten Focus-Group-Discussions (FGD) were held to evaluate the impact of the KG including 43 men, 46 women from the study group. Discussion focused on: i) what participants liked about the project? ii) what is the impact on individuals, households, the community? iii) which challenges occurred, how were they solved? iv) how children and women were affected by the project? Coding was done in cycles and categories of analysis were developed. Baseline showed that the perceived distance to the preferred marketplace to purchase food ranged from 16 up to 210 minutes. The FGD showed that the implementation of the kitchen gardens reduced the time needed to access vegetables but also the budget needed to spend on vegetables as no transport fees were needed. Participants reported that access of vegetables, sold or shared with neighbours, generally improved dietary diversity in the communities and especially of the children. Parents perceived their children to be healthier. Water scarcity hindered KG activities and households reported to have used income from vegetable sales for paying others for water fetching. Without access to vegetables and fruits a diverse diet is not possible which is associated with a high risk for malnutrition. In the study area vegetable and fruit production is limited due to water scarcity. At the same time the poverty level in Turkana is high and associated with high levels of food insecurity. The limited opportunities to purchase vegetables and fruits in the surveyed region calls for public health measures which enhance the market availability of fruits and vegetables at affordable prices.

Keywords: Co-creation, community action plans, dietary diversity, food access, kitchen gardens, time allocation

Contact Address: Irmgard Jordan, The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kaserani Rd, ICIPE Complex, 00621 Nairobi, Kenya, e-mail: i.jordan@cgiar.org

Intra-household factors under different irrigation arrangements affecting irrigation-nutrition pathways in smallholder farm households in Kenya

Nixon Murathi Kiratu[1], Eefje Aarnoudse[2], Martin Petrick[1]

[1]*Justus-Liebig University Giessen, Inst. of Agricultural Policy and Market Research, Germany*
[2]*Bonn-Rhein-Sieg University of Applied Sciences, Intern. Centre for Sust. Dev., Germany*

Women empowerment, production diversity and farm income remain three vital nutrition pathways for irrigating smallholder farm households within sub-Saharan Africa local food systems. Interlinkages of these pathways with household factors makes it a key entry point for nutrition-sensitive food system initiatives. Unfortunately, factors affecting irrigation-nutrition pathways remain largely understudied. Additionally, socio-technical set-up in which irrigation takes place has given rise to different irrigation arrangements that necessitates intricate disaggregated analysis. Such analysis is missing in literature despite its dire need and ramification to policy and developmental course of the region. Using cross-sectional data from smallholder farm households in farmer-led irrigation (FLI) and public irrigation scheme (PIS) arrangements in rural Kenya, a Heckman two-step regression model is used to analyse intra-household factors that affect the three irrigation-nutrition pathways and dietary diversity. Results show that women empowerment in FLI households was affected by age of household-head, asset ownership and primary female decision maker's community group membership. In PIS households, it was affected by household-size, renting-in land and decision-making and credit access dynamics within the household. Household access to credit and land access were found to be significant determinants of production diversity for households in PIS arrangement while access to hybrid seeds affected it for households in FLI arrangement. Land tenure and livestock keeping were found to be key determinants of production diversity across irrigation arrangements. Factors related to land access significantly impacted farm income for households in both irrigation arrangements. Hybrid seeds and group membership by the primary female decision maker were found to be determinants of farm income for PIS and FLI households respectively. Dietary diversity of FLI households was determined by access to credit by the primary female decision maker and to non-farm income and in-kind credit. Assets and age of the household head were found to affect dietary diversity of PIS households. Livestock keeping determined dietary diversity for all households. This research shows that different factors affect women empowerment, production diversity and farm income in households in different irrigation arrangements. There is therefore need to have policy specific approaches and initiatives that makes irrigation more geared towards nutritional outcomes.

Keywords: Dietary diversity, farm income

Contact Address: Nixon Murathi Kiratu, Justus-Liebig University Giessen, Inst. of Agricultural Policy and Market Research, Unterhof 69-1006, 35392 Giessen, Germany, e-mail: nixonstudy@gmail.com

Women, products from associated species with cocoa trees and food security of cocoa-producing households in central Côte d'Ivoire

Affia Sonmia Francia Kossonou[1], Venance-Pâques Gniayou Kouadio[2], Bruno Kouassi Kpangui[3], Constant Yves Adou Yao[4]

[1]*University Jean Lorougnon Guédé, Agroforestry, Côte d'Ivoire*
[2]*University Félix Houphouët-Boigny, Côte d'Ivoire*
[3]*University Jean Lorougnon Guédé, Environment, Côte d'Ivoire*
[4]*University Félix Houphouët-Boigny, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire*

Products from companion species of cocoa trees are among the natural resources that women in central Côte d'Ivoire use to diversify household food consumption and improve their income. The lack of data to assess the importance of species associated with cocoa trees to the food security of the households visited is one of the obstacles to their promotion. The objective of this study, carried out in central Côte d'Ivoire in the forest-savannah transition zone, was to analyse the contribution of species associated with cocoa trees in agroforestry systems to the diet and food security of households of women involved in cocoa production in this rural area. To achieve this objective, semi-structured interviews were conducted with women to collect data on their food habits and consumption in order to assess the level of self-sufficiency and food security of households. To do this, the CARI (Consolidated Approach to Reporting Food Security Indicators) methodology, which is used to analyse food insecurity and establish its prevalence within a population, was applied. Analysis of the data collected shows that out of 268 women involved in cocoa production, more than 30 % of women own a cocoa farm. Concerning the species associated with cocoa trees, they are composed of fruit and forest species. A total of 79 plant species have been identified, divided into 67 genera and 31 botanical families. The species that are strongly present are *Musa paradisiaca*, *Persea americana*, *Citrus sinensis*, *Elaeis guineensis*, and *Mangifera indica*. In general, the species associated with cocoa trees are used for self-consumption and sale. For other services, they serve as a source of shade, pharmacopoeia, social aspect (donation and reception of guests), as bio-fertiliser, lumber and firewood. The study shows that 12 % of households surveyed are food insecure, of which 4 % are severely food insecure and 8 % moderately food insecure. Less than 25 % of the populations assessed were heavily engaged in coping, stress and crisis strategies at the time of this work. These results shed more light on the contribution of cocoa-based agroforestry systems to the survival of the local population and the level of food security.

Keywords: Cocoa agroforestry systems, Côte d'Ivoire, food security, food self-sufficiency, gender

Contact Address: Affia Sonmia Francia Kossonou, University Jean Lorougnon Guédé, Agroforestry, Tazibouo, Daloa, Côte d'Ivoire, e-mail: kossonouafrancia@gmail.com

Promoting food security in Zimbabwe by addressing adoption challenges for female farmers: Pfumvudza agricultural program

Safiyya Kassim, William Nkomoki

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

The Pfumvudza agricultural program in Zimbabwe seeks to enhance food security and agricultural productivity by promoting sustainable agricultural practices among smallholder farmers. The program promotes the adoption of new agricultural practices, including crop diversification, conservation agriculture, and sustainable land use, among farmers, particularly smallholder farmers. While the programme holds great potential, female smallholder farmers in Zimbabwe encounter significant challenges in embracing and implementing it effectively. One of the primary obstacles encountered by female smallholder farmers is limited access to essential resources such as land, finance, and agricultural inputs. Insufficient access to land restricts their ability to expand their farming activities and limits their potential yields. Inadequate access to finance makes it difficult for them to invest in necessary inputs and technologies, hindering their productivity. Additionally, limited knowledge and technical skills in the new farming practices pose a significant barrier. Lack of training and awareness programs restricts their capacity to adopt innovative techniques and adapt to changing agricultural trends effectively. Furthermore, gender inequalities, cultural norms, and patriarchal attitudes restrict women's participation and decision-making power in agricultural activities, exacerbating these challenges. To promote the widespread adoption and success of the Pfumvudza program, it is imperative to address the structural and cultural barriers that hinder the participation and decision-making power of female smallholder farmers. Hence, to overcome these barriers, gender-responsive policies and programmes are necessary, ensuring equal access to resources, knowledge, and decision-making for all farmers. By addressing these challenges, female smallholder farmers can fully participate in the Pfumvudza program, contributing to improved food security and agricultural productivity. This study aims to propose policy interventions and strategies (favorable to female smallholders) to overcome these challenges. Research conducted in the Goromonzi district with 180 female farmers aims to identify practical approaches for empowering and enabling women's full participation in agriculture. By addressing the identified barriers and promoting gender equality, the study aims to enhance food security, increase agricultural productivity, and foster sustainable rural development in Zimbabwe.

Keywords: Conservation agriculture, female, food security, pfumvudza, smallholder farmers, sustainable, Zimbabwe

Contact Address: William Nkomoki, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences; Dept. of Economics and Development, Kamycká 129, 16500 Prague, Czech Republic, e-mail: nkomoki@ftz.czu.cz

ID 891

Livelihood diversity, dietary diversity and resilience: Findings from rural households in the Bolivian Amazon

Matthias Finckh[1], Daniel Callo-Concha[2], Oliver Frör[3]

[1]*University of Hohenheim, Germany*
[2]*University of Bonn, Center for Development Research (ZEF), Germany*
[3]*University of Kaiserslautern-Landau (RPTU), iES Landau, Inst. for Environmental Sciences, Germany*

Food security and resilience are of great importance to rural households and closely connected with their livelihoods. In the Amazon basin, the rural population of Pando, Bolivia, traditionally lives from a combination of forest-based activities, agriculture, livestock raring and wage jobs. Lately, rural households were subject to increasing changes driven by a growing road network, immigration, and the exploitation of natural resources. So far there is little information regarding the status of livelihood diversity, food security and resilience in Pando. We hypothesise that the livelihood diversities of these populations, determine their food security and their overall social-ecological resilience, which are core issues for their sustainable development. Hence, we applied a dietary diversity assessment (24h recall) and a socioeconomic survey to rural households (n=91) and evaluated their interdependencies by means of descriptive statistics as well as correlations and regression analyses. Our results, shown that most households pursuit several livelihood activities (typically one main and several side activities), among which the collection of Non-Timber Forest products (predominantly Brazil nut) accounts for over 40 % of their overall income. Household dietary diversity scores are on average high (9,25 out of 12) and range from 6 to 12 indicating a diverse diet. However, against our expectations no significant correlation between household dietary diversity and livelihood diversity or specific livelihood activities were detected. The households in the region were affected by diverse environmental and socioeconomic shocks over the last years. Nevertheless, our interviews indicate that the diversity of livelihood activities, and the access to natural resources allowed households to shift between activities and thereby softening the impact of external hazards. This work contributes to the growing number of research in the region to better understand the situation of the rural population and thereby potentially improving policies to support local livelihoods and preserve the tropical rainforests in the Pando region.

Keywords: Amazon, Bolivia, dietary diversity, food security, household interviews, Pando, resilience, rural livelihood

The significance of social capital for smallholder farmers: Selected evidence on welfare from Kenya

JAMES BOSOMTWE QUAICOE

University of Hohenheim, Fac. of Agricultural Science, Germany

Poverty continues to be a challenge among smallholder farmers in Kenya. Despite the inundated interventions by the government to improve the welfare situation among smallholder farmers, food security emerges among the many socio-economic challenges that impede smallholder farmer welfare development. While other physical and human capital interventions have already been explored, the potential of social capital is not well-discovered to full length.

This study investigates the significance of social capital on smallholder farmers' food security. To achieve the research objectives, a detailed review of relevant literature was implemented together with empirical research. The empirical research was carried out using a survey conducted in Kenya in 2013 and 2015. The ordered logistic model was employed to examine the significance of social capital on smallholder farmer household food security. The result of the study reveals that household connection and interaction in the community are positively associated with household food security while connection and interaction with its immediate relation reduce household food security.

The conclusion was that social capital can potentially improve smallholder farmers' food security, but it would be more beneficial to all households when it is integrated with other food insecurity preventive strategies such as the promotion of diversification, intensification of irrigation practices, and adoption of innovative practices. Based on these results, it is recommended that policymakers should consider integrating and strengthening social institutions such as farmer based organisations (FBOs), farmer cooperatives, and development groups among others that improve household interaction and networking by supporting and promoting the tailored need for household food insecurity coping strategies.

Keywords: Food security, social capital, welfare

Contact Address: James Bosomtwe Quaicoe, University of Hohenheim, Fac. of Agricultural Science, Stuttgart, Germany, e-mail: jamesquaicoenile@gmail.com

ID 175

Off-farm livelihood diversification enhances food security among cocoa farmers in Ghana

WILLIAM NKOMOKI, SAFIYYA KASSIM, EBENEZER DONKOR, THEOPHILUS LARBI

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences; Dept. of Economics and Development, Czech Republic

Cocoa farming in Ghana, a crucial income source for smallholder farmers, faces multiple challenges including limited profitability, sustainability concerns, poor yields, and household food insecurity. To mitigate risks, farmers are increasingly engaging in off-farm activities for income diversification. This research explores the socioeconomic factors influencing off-farm engagement, evaluates its impact on income diversification and output, and investigates the limitations of cocoa production in the study area. Data was collected through interviews and surveys, employing descriptive statistics, regression analysis, and nonparametric tests. The study emphasises the significance of off-farm work in boosting income and output for cocoa farmers. Age, farming experience, and land ownership influence the likelihood of engaging in off-farm jobs. Age and land ownership positively correlate with off-farm engagement (P-value 0.066 and 0.010, respectively). At the same time, farming experience exhibits a negative correlation, suggesting that less experienced farmers are more likely to adopt off-farm jobs. Limited access to credit and health concerns also play a role in off-farm engagement among cocoa farmers. Several challenges associated with cocoa production were uncovered, including limited land size, ageing farmers, child labour, unfavourable land tenure laws, and climate change. Farmers with off-farm jobs demonstrated higher incomes and outputs than those without such diversification. These findings contribute to the understanding of sustainable cocoa farming and rural livelihood strategies in Ghana, emphasising the importance of promoting off-farm opportunities to enhance income and household food security. Based on these findings, policy recommendations are proposed: promote off-farm opportunities, improve access to credit, implement sustainable land management practices, provide farmer education and training, and strengthen efforts to eradicate child labour. These recommendations aim to support sustainable cocoa farming, increase farmer incomes, improve household food security, and create a resilient agricultural sector in Ghana.

Keywords: Challenges, cocoa farming, household food insecurity, income diversification, off-farm activities, smallholder farmers, sustainability

Contact Address: William Nkomoki, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences; Dept. of Economics and Development, Kamycká 129, 16500 Prague, Czech Republic, e-mail: nkomoki@ftz.czu.cz

Rural entrepreneurship and food insecurity in Ghana

Bernard Kwamena Cobbina Essel, Emmanuel Tetteh Jumpah

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Czech Republic

Non-farm enterprises (NFE) play a critical role in improving the well-being of rural households by providing opportunities for income diversification, which can reduce household poverty and food insecurity. Significant progress has been made in reducing the proportion of undernourished people in Ghana. However, Ghana's progress in achieving food security has been uneven, with many farmers and rural dwellers still experiencing poverty and food insecurity. Using data from the Ghana living standards survey round 7 (GLSS7), we examine the impact of household participation in NFEs on food insecurity among rural farming households in a sub-Saharan African country. Specifically, we measure household food insecurity profiles and estimate the causal relationship between household participation in NFEs and food insecurity within a multidimensional poverty framework in rural Ghana. The results show 64 percent of households indicated they were worried about not having enough food while 63 percent were unable to eat healthy and nutritious food. About two-thirds (67 %) of households lacked food diversity by eating only a few kinds of food. Only 12 percent of households report that a member went without food for a day. We also find that food insecurity among rural agricultural households in Ghana is moderately high, with an incidence of 65 % and a food insecurity index of 49 %. Male-headed households experience slightly higher levels of food insecurity than female-headed households. Still, household participation in non-farm enterprises reduces the probability of food insecurity by 25 percentage points, or about 36 %, compared to the average incidence of food insecurity among households not participating in NFE. Given their high impact on poverty reduction and household food security, we conclude that government enterprise-focused programmes should prioritise support for rural NFEs.

Keywords: Food insecurity, Ghana, households, non-farm enterprises, poverty

Contact Address: Bernard Kwamena Cobbina Essel, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Economics and Development, Kamýcká 129, 16500 Prague-Suchdol, Czech Republic, e-mail: esselb@ftz.czu.cz

ID 519

Enhancing sustainable food security and transforming food systems in four woredas of Gurage zone, Ethiopia

Kebede Chaka[1], Degefa Chaka[2]

[1]*Keam Business and Development Consultants Plc, Ethiopia*
[2]*Oromia Regional Bureau of Agriculture, Food Security, Ethiopia*

Food systems must be appraised holistically with consideration of the potential trade-offs and synergies in the economic impacts (e.g. incomes, profits, taxes and food supply), social impacts (e.g. gender equality, nutrition, and animal welfare), and environmental impacts (e.g. the conservation of ecosystems, biodiversity, soil and water). In Ethiopia, over 20.1 million people are food insecure, including 2.73 million internally displaced people (IDPs) and 1.88 million returnees. Food system in Ethiopia is characterised by prevalence of extreme poverty and hunger, unaffordability of healthier diets, and dietary composition. Ethiopia seeks to use a sustainable and healthy-diet centred lens to transform food systems, uniting around a common goal of healthy and sustainable diets for all. To contribute to such national objectives of Ethiopian Gov't in this regard, the current study was initiated, the baseline survey conducted and study report prepared. The study area is Sodo, Debub-Sodo, E/Maskan and Marako Woredas of Gurage Zone, Ethiopia. Crop (73 %) and livestock (16 %) productions are the prominent economic activities, complemented by off-farm activities (11 %), in the study areas. This research analysed existing situations of food security and food systems in the four study areas, in six sample Kebeles. The study targeted total of 24 (women groups, youth and mixed groups) for FGDs, and 12 KIIs. Moreover, 600 HHs were sampled for HH survey via systematic random sampling methods. Descriptive statistics and econometric data analysis have been applied. The results indicated that the areas are characterised by low production & productivity, no sustainable food security, poor nutrition of women and children, and the food systems are so poor (production, processing, transportation & consumption), which needs to be transformed. Household dietary diversity score (HDDS) of 600 women is 3.35 and individual dietary diversity score (IDDS) of infants (6–36 months) is 1.62, and 80 % of target households use 1–2 food groups (HDD). The study recommended that enhancing supply of agricultural technologies & knowledges, financial inclusions, environmental protections and skill trainings within the communities of the study areas have paramount roles in curbing the existing low level of food security and transforming the food systems.

Keywords: HDDS, food groups, food systems, IDDS, synergies, trade-offs

Contact Address: Kebede Chaka, Keam Business and Development Consultants Plc, 1000 Code 1251 Addis Ababa, Ethiopia, e-mail: keam.waeb@gmail.com

Spatial modelling of food product ecosystem service for evaluated food security in Iran (case study: Qazvin province)

Naghmeh Mobarghaee[1], Houman Liaghati[1], Mostafa Keshtkar[1], Saba Shokrollahi[2]

[1]Shahid Beheshti University, Environmental Planning, Iran
[2]Tehran University, Environment, Iran

Food security exists when all people always have adequate, healthy, and nutritious food along with physical and economic access to food. However, population growth and change in the pattern of Food consumption, Lead to increased consumption and greater demand than food production levels. security food monitoring along population growth Cultivation restrictions are essential but a Lack of spatial indicators for evaluating balance and parity and heterogeneity of economic and social systems leads to estimates with high uncertainty. In this research for solving this problem, the development of a spatial model for evaluating food security indicators is investigated. Food security indicators used for this research are protein supply average, crop production, average adequacy of dietary calorie supply, and the average value of food production that in pixel scale and political boundary Qazvin province investigated. By field survey, landuse data was prepared and crop yield modelling information for each section of land use was calculated. By using the spatial model and Python, food security for tree strategic crop: wheat, barley, and rice was modeled. Results of this research show that Qazvin province has a high level of food security in terms of food availability indicators. With Comparing to cities, most measure of food security is in BoeinZahra city and less measure in Avag city. The location of Qazvin province on a national scale necessitates the province to support the food security of the capital, but the water crisis and population growth will threaten the food security of this region. The results of this research show that using spatial patterns evaluating food security, in addition of recognise hotspot and coldspot points, prepared the cognition of overflow sites that can utilise in spatial scenario compilation

Keywords: Cultivated pattern, ecosystem service, landuse planning, nexus, sustainable agriculture

Contact Address: Naghmeh Mobarghaee, Shahid Beheshti University, Environmental Planning, Velenjak, Tehran, Iran, e-mail: n_mobarghei@yahoo.com

ID 674

Assessing the factors influencing fish consumption frequency among households in Kibera informal settlement

Ferdinand Kamidi Isabu, Oscar Ingasia Ayuya, Eric Obedy Gido

Egerton University, Agricultural Economics and Agribusiness Management, Kenya

Global food and nutrition insecurity has been increasing and hence making it difficult to manage the growing population, especially in urban areas. This urban growth has led to the rise of informal settlements, nutrition insecurity, poor sanitation and food shortage. Fish as an important source of animal proteins, omega‑3 fatty acids, vitamins, and minerals necessary for normal body functioning has been proven to boost food security and reduce under-nutrition among developing countries. Health concern over the consumption of red meat has been on the rise hence consumers are shifting to the consumption of white meat, including fish. This study assessed the factors influencing the frequency of consuming fish among households in informal settlements using the ordered logit model. A sample unit of 385 households was selected through a pre-tested structured questionnaire using a stratified random sampling technique. Consumption frequency was measured by the number of times fish was consumed in a month. Empirical results showed that the majority of households 40.78 %, consumed fish between 2–3 times a week, 26.75 % at less than once a week, 16.10 % at 4–6 times a week while 15.84 % consumed once a week. The least consumers at 0.52 % consumed once a day. Gender, education level, monthly income, occupation, migration, processed fish, price, neighbourhood effect, time taken to the nearest outlet and number of outlets within a 100-metre radius influenced the frequency of fish consumption. The frequency of consuming fish was seen to be low among the majority of the consumers since only 0.52 % of households were able to consume fish at least once a day compared to those who consumed fish between 2–3 times a week at 40.78 %. This implies that fish is relatively expensive since very few households can afford it daily. To increase the frequency of fish consumed in the informal settlements, there is a need to increase the availability of high-quality fish processed in the market and also increase the income sources since this increases the rate at which fish is consumed. There is also a need to increase awareness of the health benefits associated with fish consumption among consumers.

Keywords: Fish consumption, food security, frequency of fish consumption, informal settlements, Kibera- Kenya

Contact Address: Ferdinand Kamidi Isabu, Egerton University, Agricultural Economics and Agribusiness Management, Box 536 egerton, 20115 Njoro, Kenya, e-mail: kamidi.ferdinand@gmail.com

Can trade facilitation policies help mitigate future food crises? Evidence from the Kingdom of Jordan

Sara Ashour

Humboldt-Universität zu Berlin, Agriculture Sciences, Egypt

Jordan like many Near East and North Africa (NENA) countries, relies heavily on trade to secure its basic food needs. Recent statistics show that 11 out of 13 NENA countries with available data had cereal import dependency ratios above 50 percent over the years 2016–2018 reaching up to 90 percent in all of the Gulf Cooperation Council (GCC) countries and even 100 percent in Jordan and the United Arab Emirates. MENA Region might not be the worst in terms of food insecurity but its high dependency on fertilisers and food requirements make it highly vulnerable to global disturbances in the future. With 2022 marked as a year of unpreceded hunger, and with forecasts that 2023 will not be any better, the global trade system seems to have a greater burden on its shoulder to deliver on the promises of achieving food security. Trade facilitation policies play an essential role with regard to moving food from food surplus to food deficit locations. Hence, and through mixed quantitative and qualitative methods, this study will examine the role of trade facilitation policies as a mitigating tool to achieve food security in import-dependent countries, especially in light of climatic and geopolitical risks and with application to the kingdom of Jordan.

Keywords: Crises, food security, Jordan, trade facilitation

Contact Address: Sara Ashour, Humboldt-Universität zu Berlin, Agriculture Sciences, 8. tunis street. maadi, 00000 Cairo, Egypt, e-mail: sara.samir.89@gmail.com

Do agricultural cooperatives enhance rural transformation?

GHISLAIN B. D. AIHOUNTON[1], WADOUDOU MAKPENON[2],
EKUNDAYO GLORIA CHRISTELLE GBENOU[3]

[1]*University of Parakou, Lab. of Analysis and Research on the Economics and Social Dynamics, Benin*

[2]*African School of Economics, Benin*

[3]*University of Abomey-Calavi, Lab. of Biomathematics and Forest Estimates (LABEF), Benin*

It is largely argued that rural institutions have the potential to improve farm performance and contribute to poverty alleviation in developing countries. Farmer cooperatives, standing as one of these institutions, have received increasing attention as a potential vehicle to enhance agricultural intensification and farm performance for smallholder farmers. Numerous previous studies have shown that farmer cooperatives generally increase agricultural productivity and profitability. However, other aspects of welfare such as food security, and market orientation are not yet understood. Moreover, although in most rural household settings, farmers usually receive agricultural extension through their active participation in cooperatives, there is still a scarcity of knowledge on the extent to which belonging to farm cooperatives, could enhance farmer's technical know-how as important pathways to transforming food systems in developing countries. Using data from rice-growing households in Côte d'Ivoire, we investigate the effects of belonging to an agricultural cooperative on farm performance, specialisation, and food security. We also explore the effects of farmer cooperatives on access to extension services and farmer technical skills. Employing instrumental variable techniques, we show that farm cooperatives improve important aspects of household welfare. Specifically, agricultural cooperatives improve agricultural productivity, and profitability and translate into high commercialisation potential for rural households. Using the FAO household food insecurity experience scale and the household dietary diversity score, we also show that belonging to an agricultural cooperative improves household food and nutrition security. The key mechanisms include access to extension services, the adoption of modern technologies, the acquisition of knowledge on improved agronomic practices, and access to markets. Hence, farmer's cooperatives can be considered as vectors of welfare and thus an essential pathway to enhance rural transformation in developing countries.

Keywords: Cooperative membership, food security, rural transformation

Contact Address: Ghislain B. D. Aihounton, University of Parakou, Lab. of Analysis and Research on the Economics and Social Dynamics, Parakou, Benin, e-mail: aihountong@gmail.com

Effects of credit constraints on the welfare of farm households in Southwest Nigeria

Dorcas Fadoju[1], Olufunmilola Adesiyan[2], Damilola Adeomi[1]

[1]*Development Agenda for Western Nigeria (DAWN Commission), Agriculture and Agric-business Desk, Nigeria*

[2]*Obafemi Awolowo University, Dept. of Agricultural Economics, Nigeria*

This study examined the effect of credit constraints in farm households' welfare in Southwest Nigeria with a view to understanding credit constraints impacts on the welfare of farm households in the study area. A multi-stage sampling technique was employed in the selection of 320 households for the study. The primary data were collected with the aid of pre-tested and structured questionnaire. The data collected were analysed using multinomial endogenous switching regression model. The multinomial endogenous switching regression result showed that risk constrained households would have a higher welfare if they paid their last loan while quantity constraints households would have a higher welfare if their household head had more years of formal education, pay their last loan back and owned lands. Transaction cost constrained households would likely fare better if their households were headed by males, and had smaller household size. Unconstrained household will have their welfare reduced if they have larger households while social capital increases their level of welfare. Furthermore, the result showed that risk, transaction costs and quantity constraints caused a welfare loss of 9.76 %, 6.18 % and 65.7 % respectively and therefore removal of risk constraints, transaction cost constraints and quantity constraints will cause a welfare gain for the farming household. The study concluded that credit constraints had serious impact in farm household's welfare and that credit unconstrained households have higher levels of welfare than the constrained ones. Household size, gender of household head, social capital, repayment history, education are factors determining the welfare of the household credit categories. Finally, the households would be better off if they were credit unconstrained.

Keywords: Credit constraints, farm households, multinomial endogenous switching regression model, welfare

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Contact Address: Dorcas Fadoju, Development Agenda for Western Nigeria (DAWN Commission), Agriculture and Agric-business Desk, 10th floor cocoa house building, Ibadan, Nigeria, e-mail: fadojutolu89@gmail.com

Sociocultural factors influencing production and consumption of fruits and vegetables in Boukombé in northern Benin

Malikath Bankole[1], Sam Bodjrenou[2], Mélina Houndolo[1], Waliou Amoussa Hounkpatin[1], Céline Termote[3]

[1]*University of Abomey Calavi, Fac. of Agronomic Sciences, Benin*

[2]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Benin*

[3]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya*

Fruits and vegetables (F&V) are vital for healthy diets, with a broad consensus that a diversified diet containing a range of plant foods is needed for health and well-being. Although the African continent is considered to have a huge diversity of F&V, we are witnessing a decrease in the production and use of some of them. This study investigated the reasons behind the low production and use of some F&V species in the commune of Boukombé in the Atacora department, this commune is one of the most food insecure in Benin. Qualitative approach especially the snowball method has proceeded to select the key informants constituted of market gardeners and institutions involved in agriculture in Boukombé. The 4-cells method was used to collect information about production and consumption and then semi-structured interviews as well as focus group discussions were used to better understand the perceptions of the market gardeners.

Fruits and vegetables were the most represented species with respectively 34.6 % and 27 % of species available. About 60 % of F&V species identified were perennial while 40 % were annual and most of them were cultivated by the population. Only 28 % were grown wildly in nature and few were semi-cultivated. Among the species cultivated, many were identified as being grown in a small area by a few people and as being consumed by a small number of people occasionally. The main reasons that explain this low production were essentially the inaccessibility of roads from villages to markets, the perishability of F&V, the soil poverty, the lack of water sources because those villages are located on the mountains, and the high seed prices of some F&V such as carrots, cabbage, and lettuce. This induced a low consumption of these species which were lowly available in the environment. In addition, there were the deforestation practices and then, the lack of knowledge about the conservation of F&V species, as well as their market value which made populations prioritise their sale over their consumption.

Meanwhile, several strategies were proposed including the establishment of community seed banks to improve the production and consumption of F&V species in their community

Keywords: Benin, consumption, fruit and vegetables, production, qualitative method

Contact Address: Malikath Bankole, University of Abomey Calavi, Fac. of Agronomic Sciences, Abomey Calavi, Benin, e-mail: bmalikath73@gmail.com

Effect of food environment on urban dwellers' dietary diversity in southwest Nigeria

Ifeoluwa Ola[1], Oluwafunmiso Adeola Olajide[2]

[1]University of Ibadan, Agricultural Economics, Nigeria
[2]University of Ibadan, Dept. of Agricultural Economics, Nigeria

Unhealthy diets and bad consumption patterns are at the root of all forms of malnutrition. There is a shift from the consumption of micronutrient-rich, less dense energy foods such as vegetables and fruits to dietary intakes of micronutrient-poor, energy-dense foods. Food environment has emerged as a powerful influence on individuals' eating patterns, food choices, and diet quality. In the urban and peri-urban communities, the availability of retail outlets with wide variety of affordable and nutritious food and its accessibility plays a significant role in consumer dietary choices and adoption of a balanced diet. The study seeks to identify the true effect of food environment on urban dwellers' dietary diversity in Southwest Nigeria. Primary data on consumers and retailers characteristics will be collected, given their role in the food environment, and analyzed. A linear regression model will be used to identify the relationship between dietary diversity and food environment. Other tools to be employed include: Market-level diversity score and Household dietary diversity score. The expected result will reveal a positive relationship between adequate food environment and quality of household diet. The study is expected to provide insight for both public and private sector policymakers to formulate policies that will create a healthy food environment for the populace. This will inform policies aimed at (i) increasing the availability/promotion of healthy food and drinks (i.e., nutrient-rich, fresh or minimally processed foods), (ii) decreasing the availability/promotion of unhealthy food and drinks (i.e., energy-dense nutrient-poor foods, sugar-sweetened beverages), and (iii) improving the nutritional quality of food available within the food supply chain, most especially particular processed foods and out-of-home meals.

Keywords: Dietary diversity, food environment, market-level diversity score, household dietary diversity score

Contact Address: Ifeoluwa Ola, University of Ibadan, Agricultural Economics, Oyetoro hostel orogun, Ibadan, Nigeria, e-mail: ola.ifeoluwa@yahoo.com

Food environment and consumer behaviour for improved nutrition and health

Evaluation of the attractiveness of four variations of infant food packaging label using eye tracking

Ina Cramer[1], Iris Schröter[1], Diba Tabi Roba[2], Hussein Wario[2], Marcus Mergenthaler[1]

[1]*South Westphalia University of Applied Science, Agricultural Economics, Germany*
[2]*Center for Research and Development in Drylands, Kenya*

High child malnutrition in African drylands is, among other factors, influenced by choice of child food. Local women groups produce healthy, affordable child foods based on traditional recipes, but are in need of appealing packaging to compete with multinational companies. This study is part of a number of investigations aimed at empowering women groups in northern Kenya by co-developing attractive packaging designs. The input of the members of a local women group resulted in four variations of an infant porridge packaging design derived from previous own investigations. All four designs are identical with two exceptions: They have either a red or a yellow background and display either a zebra or a lion, resulting in the following combinations: 'Red Lion', 'Yellow Lion', 'Red Zebra' and 'Yellow Zebra'. To evaluate the attractiveness of the four variations of the packaging design and identify the most attractive one, a market situation was re-created: the porridge packagings were displayed on tables and a total of 87 participants, who received an expense allowance, were each asked to choose one bag of porridge. The eye movements of 81 participants were recorded using eye tracking glasses. Participants were interviewed to gain insights in the reasoning leading to their decision and answers were recorded using an online form. The majority of participants chose the 'Red Zebra' design (n=31), followed by 'Red Lion' (n=23), 'Yellow Lion' (n=22) and 'Yellow Zebra' (n=11). The participants indicated a high interest in buying the product on the market and stated that they were prepared to pay a mean price, according to the packaging option, ranging from 118 Kenyan Shillings (SD 43) to 140 Kenyan Shillings (SD 60). The 'Yellow Lion' packaging received the most visual attention, followed by the 'Red Zebra', 'Red Lion' and 'Yellow Zebra'. Our results indicate that the colour red was found to be particularly attractive and while there is no clear preference for either the zebra or the lion, it is advisory for the women group to include red as a dominant colour in their packaging. The eye tracking results support this result only partially and further analysis are necessary.

Keywords: Eye tracking, food choices, infant food packaging, malnutrition

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Contact Address: Ina Cramer, South Westphalia University of Applied Science, Agricultural Economics, Lübecker Ring 2, 59494 Soest, Germany, e-mail: cramer.ina@fh-swf.de

What meat attributes do consumers in Afghanistan value the most? – An analysis of choice attributes

MUSTAFA NASIRI, BIRGIT GASSLER, RAMONA TEUBER

Justus-Liebig University Giessen, Inst. of Agric. Policy and Market Res., Germany

Global meat production continues to expand to meet rising demand, spurred mainly by population and income growth in developing countries. With the increased production, the demand for meat quality and safety is also rising due to growing consumer concerns and awareness. To make quality inferences, consumers evaluate certain meat attributes, which in turn, influence purchase decisions. Moreover, understanding preferences for meat attributes is crucial for producers, traders, and government to enhance marketing strategies, trade and public policies. This study examines the relative importance of thirteen mutton meat attributes in a choice experiment study using the Best-Worst Scaling (BWS) method. The data was obtained through a laboratory-based survey from 230 male (60 %) and female (40 %), young and educated consumers in Kabul, Afghanistan during Jan – Mar 2021. The data was analysed based on the maxDiff method of BWS, utilizing both counting and modelling approaches. Results revealed that food safety certification, freshness, Halal-label, taste, cleanliness, and origin are consecutively the most important attributes. Furthermore, food safety as the most important attribute was nearly 12 times as important as color which was the least important attribute, suggesting that food safety is not just a concern for the developed country consumers, but rather a global health concern. The study also incorporated individual specific characteristics; socio-economy, risk-taking attitudes, and place of purchase into the model to study the effect of these characteristics on the mean parameters. Results revealed that preferences for meat attributes are heterogenous among different consumer groups. Food safety certification, Halal-label, brand, freshness, and animal-breed are of significantly higher importance for consumers with higher level of education and income. Food safety and freshness are also of significantly higher importance for young aged consumers. Furthermore, risk loving individuals place significantly higher value for freshness, while significantly lower value for food safety. Additionally, butchery shoppers place significantly higher importance on animal welfare, food safety, and quality appearance. The study may help domestic meat producers enhance their marketing strategies, and government in planning trade and public policies in developing countries given the growing trend for modernisation of meat industry in these countries.

Keywords: Best-Worst Scaling, choice experiment, food safety, freshness, Halal-label, meat attributes, origin, preferences

Contact Address: Mustafa Nasiri, Justus-Liebig University Giessen, Inst. of Agric. Policy and Market Res., Giessen, Germany, e-mail: mustafa.nasiri@agrar.uni-giessen.de

Exploring the determinants of a healthy food nutrition environment in rural households

Ronald Ochieng Mwanga[1], Stefan Sieber[1], Constance Rybak[1], Jacob Kaingo[2], Hadijah Mbwana[3]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany*
[2]*Sokoine University of Agriculture, VEGILEG Project, Tanzania*
[3]*Sokoine University of Agriculture, Human Nutrition and Consumer Sciences, Tanzania*

Developing countries have recently undergone food environment transformations characterised by increased consumption of unhealthy ultra-processed foods, resulting in an increased incidence of the double burden of malnutrition. Despite the ongoing dietary transitions, the food environment has been researched mostly focused on developed countries. The food environment encompasses the availability, affordability, convenience, and desirability of various foods and is the node between broader food systems and individual or household diets. It is thus imperative to study and evaluate determinants of a healthy food environment and formulate policies that influence food environments for healthy diets, particularly in rural households in low and middle-income countries. Our research aims to characterise the rural food environment, analyse factors that influence the food environment, and explore policy interventions that could transform the food environment to promote the uptake of nutrient-dense diets in rural households in low-income countries. We use the Lindi Region of Tanzania as a case study and qualitative methods to define the food environment based on food accessibility and availability measures including diversity and proximity. We developed an open-ended questionnaire for data collection based on the socioecological model of dietary behaviour and conducted seven focus group discussions made of 10 participants (n=70), identified through a purposive sampling technique. We also conducted four expert interviews with the District Nutritional and Agricultural officers. The data was then transcribed, coded, and analysed through framework analysis using the MAXQDA® qualitative data analysis tool. Our results reveal that proximity to healthy food, seasonality, specific to fruits and vegetables, physical and economic accessibility, and availability of healthy food items determine consumer choices. Additionally, at the individual level, cost, convenience, availability, and sociocultural norms determine household dietary patterns. Therefore, for rural households, food nutrition education, production diversification, infrastructure development, and post-harvest processing and conservation techniques are touted as the most appropriate policy instruments that would ensure a healthy food environment and sustainable food security.

Keywords: Dietary patterns, food environment, nutrient-dense

Contact Address: Ronald Ochieng Mwanga, Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Oberfeldstrasse 132, 12683 Berlin, Germany, e-mail: rnldmwanga@yahoo.com

ID 704

Community action plans to enhance sustainable food availability and accessibility in Busia County, Kenya

Irene Induli, Francis Oduor, Irmgard Jordan, Céline Termote

The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Kenya

On-farm or landscape biodiversity and diet diversity are positively linked. Rural families often depend on their own farm production for food security. Eating a variety of foods across food groups is associated with sufficient intake of several micronutrients and subsequent good health. In Teso North and South sub-counties of Busia, 20 community units were randomly selected, 10 from each sub county. A cross-sectional survey including 400 women with children 6–23 months was conducted to identify challenges in dietary practices. This informed a co-creation process with 10 out of the 20 community units (5 from each subcounty). They took part in a series of participatory workshops to identify solutions to the dietary challenges and developed community action plans with interventions that were implemented for one year. The co-creation process included community members, researchers, and the county government. Monitoring and evaluation took place throughout the implementation period. At baseline, 42 % of the households owned kitchen gardens. Less than 10 % had received training in kitchen gardening. About 63 % of surveyed children met the minimum dietary diversity score (4 out of 7 food groups), while only 30 % of women met the minimum score, 5 out of 10 food groups. To improve the availability, accessibility and consumption of diverse foods, the communities implemented selected interventions which included ground nuts, fruits, vegetables, orange-flesh sweet potato farming, and poultry keeping. All community groups registered as self-help groups through which the members conducted table banking to raise capital to fund selected intervention activities. Community health workers (n=117) were trained in nutrition education and counselling and cascaded the knowledge to 17,167 households within their villages. Twelve agricultural demonstration gardens and 5 poultry projects were established. 232 farmers trained in kitchen gardening, entrepreneurship, financial records, and book-keeping. Analyzed endline data will be presented at the conference. The co-creation process enhances community participation and ownership of intervention activities. Since the community members have invested their financial and human resources in the intervention activities, they are committed to their success. Active government involvement in the process is vital.

Keywords: Co-creation, community action plans, community participation, dietary diversity

Southern African diet: Developing a regional diet for better health for people and planet

Judith Henze

Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Germany

The decline in nutritional value of many food products, progressively limited diversity of crops and livestock, as well as recent price and production shocks, are emphasising that a large-scale transformation of our global food systems is urgently needed to ensure that it becomes more equitable and sustainable. Rather than continuing to back a global diet that is heavily fixated on a handful of crops and breed, such as wheat, rice, maize, rapeseed, and Holstein cows, we need regional and local diets. In practice this means to progress regional diet concepts such as the widely known Mediterranean Diet, or the Nordic Diet, promoted by chefs in Sweden, Denmark, Finland, and Iceland. Local adaptations of the Mediterranean Diet could be an Australian Diet, a Southern American Diet and yes, a Southern African Diet, with scope for dietary sub-regions. A key advantage would be that these local diets will be more diverse and culturally-relevant - both in terms of production and consumption. The list of benefits is long: the local and seasonal produced foods would consist of crops and livestock breeds that are native and hence better adapted to the regional climate, pests, and disease than introduced types. Shorter value-chains means reducing transport emissions. A higher biodiversity of native crops and breeds – produced via agroecological production systems – will decrease homogeneity in global food products, while moving regions towards higher food and nutritional security.

For many countries, adopting a more local food system means a decreased dependency on global food prices. For example, the local breads in Southern Africa are made with sorghum or millet rather than wheat.

Moreover, when merging this concept with the basic ideas of a Planetary Diet, as drawn up by the EAT-Lancet Commission, a food system and eating plan emerges that protects both human health and the planet alike. In my oral presentation I will highlight the many steps, (behavioural) changes and stakeholders necessary to promote and adopt the concept of regional diets such as the Southern African Diet.

Keywords: Behaviour change, diversification, local food systems, Southern African diet, transformation

Contact Address: Judith Henze, Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Robert-Koch-Platz 4, 10115 Berlin, Germany, e-mail: judith.henze.1@hu-berlin.de

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Visual perception and evaluation of child food packaging design by customers in northern Benin

Iris Schröter[1], Ina Cramer[1], Adrien Dogo[2], Franck Hongbete[2], Marcus Mergenthaler[1]

[1]*South Westphalia University of Applied Science, Agricultural Economics, Germany*
[2]*University of Parakou, Foods Sciences Laboratory, Benin*

Visual packaging attributes determine the success of a product on the shelf, create hedonic value and may influence peoples' perception of the products' intrinsic properties. While multinational child food producers successfully attract attention through appealing food packaging, small-scale producers need support in designing attractive packagings to compete in the market.

The study is part of investigations aimed at empowering women in northern Benin to successfully market their locally produced child food by co-developing an appealing packaging design: Five different child food packagings were used as stimuli – three from multinational, one from a domestic producer and one based on results of our preceding investigations. Fifteen child food customers from Parakou, northern Benin, saw the stimuli on a computer screen while their gaze behaviour was recorded by a remote eyetracker. Immediately after watching the respective packaging, the participant rated the design. Finally, a short interview was conducted.

Participants' ratings of the packaging designs differed significantly ($p < 0.001$): the designs from multinational manufacturers were rated higher than the one from Benin and our own design. However, the domestic packaging received higher ratings from participants who looked at its food quality mark. All product logos were visually visited by all participants (n=15), except the logo of the domestic product (n=10), indicating that its characteristic might not be optimal. The time to first fixation was shortest for Cerelac (multinational manufacturer) and its colour (red) was mentioned positively in the reflection part. The majority of participants visually visited the various mascots. Again, the time to first fixation was shortest for Cerelac, indicating that this mascot was highly salient, probably due to the use of intense, contrasting colours of the background (yellow) and mascot (blue bear with a winking eye). In the interview, this was the only mascot associated with fun. Combined with the high ratings of Cerelac packaging, this underpins that the women could learn from multinational manufacturers, which attract potential child food customers and consumers by using welcoming cartoon characters, bright colours and designs depicting fun, and take a similar approach when designing their own packaging. They could also seek a food label.

Keywords: Consumer perception, locally produced child food, packaging design, visual attention

Consumers' attitudes towards social e-commerce for rice and shrimps with emphasise on female entrepreneurs in Bangladesh

Shanjida Sharmin, Christin Schipmann-Schwarze, Katrin Zander

University of Kassel, Agricultural and Food Marketing, Germany

Worldwide, online markets are becoming a more popular shopping place day by day with the development of digital technologies. Among the various types of e-commerce, social e-commerce has gained popularity in developing countries. In Bangladesh, Facebook-based social e-commerce (f-commerce) is the most popular one, which is becoming an opportunity also for female entrepreneurs. Many women are starting to sell products through f-commerce, including agricultural food products. Since females are not so common in the traditional food market in Bangladesh, f-commerce could be a new opportunity for them. Very little is known about consumers' perceptions of f-commerce for food products, with an emphasise on female entrepreneurs. To address this gap, this research aims to gain insights into consumer attitudes toward f-commerce, focusing on female entrepreneurs selling rice and shrimps. Five online audiovisual focus group discussions were conducted with 41 consumers from Dhaka, Bangladesh, in June 2022. Our findings indicate that convenience and service are the main general reasons for consumers to purchase online via f-commerce platforms. In the case of rice and shrimps, consumers shop from f-commerce because of availability of specific products from some certain growing areas. When it comes to the decision for a specific f-commerce shop, price transparency, reasonable price and low delivery charge are purchase criteria. Reviews and recommendations influence consumers' purchase decisions on this social e-commerce platform. Trust in the authenticity of entrepreneurs on a f-commerce platform is an important issue for consumers.. All participants appreciate that f-commerce platforms provide economic opportunities for women, but product quality and service are more important than the gender of the seller in their decision from whom to buy. Our study suggests that to have a sustainable position in the f-commerce food market, female entrepreneurs need to meet the expectations of consumers as the consumers do not buy from them just out of good will. The research findings provide valuable suggestions for female entrepreneurs which is of great importance to adapt to consumers' demand as well as to enter the f-commerce market and prove the sales of food products.

Keywords: Consumers' perception, Facebook, female entrepreneurs

Contact Address: Shanjida Sharmin, University of Kassel, Agricultural and Food Marketing, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: sharminbau41@gmail.com

ID 275

The rise of A2 milk: Consumer demand, farmer perception, and marketing strategies in a metropolitan area

Neda Yousefian[1], Md Shahin Alam[2], Kumsher Basavarajappa Ramappa[3], Eva Schlecht[2], Christoph Dittrich[1]

[1]University of Goettingen, Inst. of Geography: Human Geography, Germany
[2]University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany
[3]Institute for Social and Economic Change, India

Since 1970 per capita milk consumption in India has quadrupled, in part due to rising incomes and urbanisation, which has spurred dietary changes. In our work we examine how the rise in dairy consumption is shaping consumer preferences and how dairy farmers are meeting these demands. We focus on direct marketing between farmers and consumers in order to understand why some consumers prefer to purchase milk directly from dairy farmers. We also explore the perceptions of dairy farmers regarding the quality of their milk and direct sales to consumers. From May to July 2022 we conducted interviews with 62 dairy farmers and 95 consumers who purchase milk directly from our sample farmers. Our study took place in urban and peri-urban regions of the south Indian megacity Bengaluru. We focused milk from indigenous zebu cows (*Bos indicus*) with the A2 variant of beta-casein as opposed to raw milk from crossbred animals (*Bos indicus* X *Bos taurus*). Our findings reveal that farmers are able to capitalize on the urban demand for farm-gate fresh milk, whereby farm-gate milk demand is primarily driven by freshness, quality, and health expectations. Furthermore, we identified a growing market for A2 milk, with urban consumers in high income and education brackets willing to pay on average 90 Indian rupees (1 Euro) for a liter, nearly double the price for a liter of regular milk. Consumers choose A2 milk for two main reasons - because of the advertised health benefits and because it comes from indigenous cattle. Farmers advertise A2 milk on social media and on their own website as healthier and more nutritious and highlighting that it comes from indigenous cattle. However, neither farmers nor consumers have a clear understanding of A2 milk certification so far. Nevertheless, there is a growing consumer demand for A2 milk and farmers who are aware can benefit from this niche market. To this end, a direct marketing relationship between farmers and consumers is vital for the farmers' livelihood and to supply consumers with milk that is commercially largely unavailable.

Keywords: A2 milk, certification, consumers, dairy farmers, India, indigenous cattle

Influence of socio-psychological food environment on consumer food choice in Mkuranga and Ilala districts, Tanzania

Eward Mushi[1], Roselyine Alphonce[1], Betty Waized[1], Mikidadi Muhanga[2], Harald Kaechele[3], Constance Rybak[4]

[1] *Sokoine University of Agriculture, Dept. of Agricultural Economics and Agribusiness, Tanzania*
[2] *Sokoine University of Agriculture, Dept. of Development and Strategic Studies, Tanzania*
[3] *Leibniz Centre for Agric. Landscape Res. (ZALF), Inst. of Socioeconomics, Germany*
[4] *Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany*

Food systems of low-income countries are experiencing increased disruptions caused by such aspects as trade patterns and globalisation, climate change and outbreak of diseases. These disruptions augment the triple burden of malnutrition (TBM), that has primarily been a consequence of the interaction between the food environment (FE) and food choices (FC). Thus, understanding of how FE influences FC is critical to addressing the TBM. Ample research on FE in the past decade is concentrated on high income countries with focus on the physiological aspects of FE rather than the socio-cultural and psychological. The paucity of research-based evidence on how FE influences FC in low-income countries could be contributing to the persistent TBM. Theory of planned behaviour (TPB) and health belief model (HBM) was applied to determine the socio-psychological constructs influencing intention and consequently choice of healthy food among 408 randomly selected adults in Tanzania. Cross-sectional data were analysed through structural equation modelling (SEM). The findings reveal that; about 70 % of the variance in intention to choose healthy foods is explained by consumer's knowledge, attitude, and perceived behaviour control ($p < 0.01$). On the other hand, health value, perceived barriers, health behavioural identity, and perceived susceptibility account for 80 % of the variance observed in the intention to choose healthy food ($p < 0.05$). Results further revealed a significant difference among the predictors of intention to choose healthy foods between rural and urban, male and female, and across age categories. We suggest that the socio-psychological aspects of the food environment should be an integral part of health and nutrition interventions. Since over 70 % of intention to choose healthy foods is influenced by socio-psychological aspects of the food environment, it is imperative that health and nutrition interventions integrate such aspects in order to improve consumers' knowledge, and foster positive attitudes and perceptions about healthy eating

Keywords: Food choices, food environment, health belief model, socio-psychological factors, Tanzania, theory of planned behaviour

Contact Address: Eward Mushi, Sokoine University of Agriculture, Dept. of Agricultural Economics and Agribusiness, P.O.Box 3007, Morogoro, Tanzania, e-mail: emushi45@yahoo.com

ID 793

Food literacy and nutrition status in rural and urban Tanzania: Exploration of the nexus

Victoria Kariathi[1], Hadijah Mbwana[1], Constance Rybak[2,3], Safiness Msollo[1], John Msuya[1]

[1]*Sokoine University of Agriculture, Dept. of Human Nutrition and Consumer Sciences, Tanzania*
[2]*Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany*
[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Inst. of Socio-Economics, Germany*

Increased rates of malnutrition are influenced by changes in food environment and requires practical knowledge and skills to intervene. Food literacy (FL) is important to provide skills and abilities required for health relationship between individuals and food environment hence supporting dietary resilience overtime. It is necessary to understand FL status of the study population to develop resilient nutrition interventions. The aim of this study was to examine the food literacy levels and nutrition status in adult population residing in rural and urban Tanzania. A cross-sectional study involving 697 adults (474 female and 223 males) sampled from rural and urban Tanzania was conducted. A structured questionnaire composed of 23 FL items was used to assess food literacy of target groups. Five-point Likert scale with very easy to very difficult choices was used. The weight and height measurements were taken for estimation of Body Mass Index (BMI). Confirmatory factor analysis was done to test if FL items explain FL construct. Internal consistency of FL was estimated using Cronbach's Alpha at significance level of 0.05. FL score of 0–50 and levels of FL in terms of inadequate, problematic, sufficient and excellent was established. FL levels were linked with gender, residence, education and BMI levels (underweight, normal weight, overweight and obesity) according to WHO standards. Mean factor loading was 0.61 and each item showed strong ability to explain FL. All FL items had excellent internal consistency ranges from 0.92 to 0.93 Cronbach's Alpha to measure FL. The study showed significant association in FL levels across gender, residence, education level and BMI. Problematic level of FL was higher (42.2 %) among other levels. Excellent FL was higher in urban (16.7 %) than rural (6.2 %). Males and females showed similar pattern in FL levels. 75 % of participants with higher degrees had excellent level of FL while those with low education fall on problematic and inadequate FL. Despite variation in FL levels, nutrition status showed similar patterns in the study population. Problematic level of FL was higher among the adults. There is a need to design nutrition educational intervention aiming at improving food literacy among the study population.

Keywords: Adults, food environment, food literacy, nutrition status, rural, Tanzania, urban

Contact Address: Victoria Kariathi, Sokoine University of Agriculture, Dept. of Human Nutrition and Consumer Sciences, P.O Box 3006, Morogoro, Tanzania, e-mail: vkariathi@gmail.com

Nutrition interventions for enhanced child health outcomes in Hanoi, Vietnam

Ha L. T. Nguyen[1], Lisa Biber-Freudenberger[2], Simone Kathrin Kriesemer[2], Eike Luedeling[3], Swe Zin Moe[4], Hoa Bui Thi Khanh[5], Thi Sau Nguyen[6], Thi Thu Giang Luu[3], Cory Whitney[3]

[1]InnoGenEx Int'l, LTD, R&D, Vietnam
[2]University of Bonn, Center for Development Research (ZEF), Germany
[3]University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany
[4]Spectrum-SDKN, Nutrition, Myanmar
[5]Vietnam National University of Agriculture, Dept. of Economics, Vietnam
[6]Fruit and Vegetable Research Insititute, Economics and Marketing Dept., Vietnam

Food environments are the underlying physical, economic, political and sociocultural conditions that determine the availability, affordability, quality and safety of food as well as the information, advertising and promotion around food.

The regular consumption of processed food and fast food is causing the rate of overweight and obese children in Hanoi to increase rapidly. We identified interventions that could improve children's diets. We applied participatory mapping and focus group discussions to co-develop a comprehensive understanding of families' interactions with urban food environments in Hanoi, Vietnam. Based on participatory maps, we generated spatial information about food access and locations for potential interventions. We included 73 food environment stakeholders in our analysis, including mothers, fathers, grandmothers, grandfathers, children, child-care specialists, "maids" and food vendors. Our research aims to identify possible interventions, for which we aim to project impacts using Decision Analysis methods. Decision Analysis is a methodology that can help decision-makers navigate complex decisions with limited information.

Potential beneficiaries of interventions were identified in small children, primary school students, and young teens, who constitute the major risk groups for poor eating habits that can lead to chronic diseases. Stakeholders noted childhood obesity, likely due to exposure and access to abundant and unhealthy, cheap and convenient food options, parents overfeeding small children and sudden social pressure to lose weight for young teens. Participants expressed concerns regarding food safety, hygiene, and chronic diseases linked to poor eating habits and proposed two concrete interventions to promote healthy habits and nutritional knowledge among children and their families:

Contact Address: Simone Kathrin Kriesemer, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: simonekriesemer@gmx.de

the establishment of farmers' markets providing healthy food and school food events raising awareness among students. Both concrete interventions aim to promote healthy habits and nutritional knowledge among children and families. The market could operate at central locations and accommodate busy schedules.

We co-identified other interventions as healthy traceable school meals, canteens for all schools, safe affordable food, food certification and labeling, self-supply through home gardens, urban agriculture, and community gardens. The next steps in our research will be to evaluate the feasibility and effectiveness of the proposed interventions, ultimately guiding the development of targeted strategies.

Keywords: Children's diets, decision analysis, gender, nutrition intervention, transdisciplinary approach, urban food environments

Perceptions and consumption of fortified food products in Ghana: The case of mushroom-fortified bread

Robert Aidoo, Faizal Adams, Gifty Boakye Appiah, Seth Etuah, Bright Kyei, Ivy A. Sowah, Marino E. Essuman, Travis Adu-Poku, Daniel Oppong, Kofi Yeboah Asare

Kwame Nkrumah University of Science and Technology (KNUST-Kumasi), Dept. of Agricultural Economics, Agribusiness and Extension, Ghana

Ghana is experiencing double burden of malnutrition with a high prevalence of undernutrition and overweight/obesity. This is partly due to the consistent increase in the consumption of refined food products like white bread in both rural and urban communities. This substantial rise in the consumption of refined food among households has led to serious nutrient deficiency, especially in areas where food is usually consumed without adequate quantities of vegetables, fruits, and proteins. Refined bread, which is a major component of the daily breakfast and bedtime meal in Ghana, is made from highly processed wheat flour with inadequate quantities of proteins, essential vitamins, minerals and dietary fiber required for proper functioning of the human body. Fortifying bread with mushrooms reduces the adverse effect of consuming refined bread by increasing its nutritional content and health benefits. This study used primary data from 406 randomly selected households to examine perceptions and consumption patterns for mushroom-fortified bread in the Ashanti Region of Ghana. Perception index, binary probit and tobit regression models were employed to analyse the field data. Evidence from the study shows that only 26 % of consumers had purchased and consumed mushroom-fortified bread, even though 63 % of bread consumers were aware of this new product on the market. Generally, consumers have positive perception about mushroom-fortified bread, especially because of its nutritional content, health benefits and superior sensory attributes. However, household consumption of this fortified food product is significantly influenced by awareness, age of household head and income level. Intensive awareness creation about mushroom fortified bread through local radio stations and social media platforms is recommended to stimulate household demand for the new product to promote good health and nutrition in Ghana.

Keywords: Bread, consumption, fortification, mushroom, perception

Contact Address: Robert Aidoo, Kwame Nkrumah University of Science and Technology (KNUST-Kumasi), Dept. of Agricultural Economics, Agribusiness and Extension, Kumasi, Ghana, e-mail: badubob@yahoo.co.uk

Consumers' willingness to pay for genetically biofortified foods: Evidence from Nigeria

Titilayo Akinwehinmi, Birgit Gassler, Ramona Teuber

Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Germany

Micronutrient deficiency is a persistent challenge in low and middle-income countries, but biofortification, which increases the density of micronutrients in staple foods, is recognised as an effective strategy. And compared to conventional breeding methods, genetic engineering has been found to be more effective in biofortification due to its ability to add multiple nutrients in a cost-effective and timely manner. However, the use of genetic engineering in biofortification remains a topic of debate. This study investigates the effect of two types of information treatments on consumers' willingness to pay for attributes of biofortified foods with a focus on breeding methods. Using the case of biofortified cassava product (gari) in Nigeria, the attributes considered are the nutrient attributes, i.e., Vitamin A and Iron, and the methods attributes, i.e., conventional breeding (CB), genetic modification (GM), and gene editing (GE) methods. A discrete choice experiment (DCE) was conducted with a representative sample of 352 participants drawn from rural and urban areas in Nigeria. Respondents were randomly assigned to one of three groups based on the information treatments: no information (control group), information on the health risks of Vitamin A and Iron deficiencies, and nutritional benefits of biofortification (nutrition group), or information on the scientific process of biofortification methods (breeding group). A balance test shows that the randomisation of the participants was successful. The DCE data were fitted to random parameter logit models. Our findings indicate that consumers initially preferred nutrient attributes but discounted GM and GE methods compared to CB. However, providing the first information treatment made consumers willing to pay for GM and GE methods. Conversely, the second information reduced the discount for GM and GE methods but the effect was not statistically significant. Overall, we observe that providing information on breeding methods made consumers focus more on nutrient-related attributes when making their choices. Although it is apparent that consumers in our study relatively prefer CB, we cautiously conclude that the use of GM and GE is not likely to significantly affect consumers' acceptance of biofortified food opening up opportunities for scaling genetically biofortified foods in sub-Saharan Africa

Keywords: Biofortification, discrete choice experiment, genetic engineering

Contact Address: Titilayo Akinwehinmi, Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Senckenbergstrasse 3, 35390 Giessen, Germany, e-mail: titilayo.akinwehinmi@agrar.uni-giessen.de

Physical activity, time use and diet in the nutrition transition of adolescents in rural India and Nepal

Oluwatosin Aderanti, Chittur Srinivasan, Giacomo Zanello

University of Reading, School of Agriculture, Policy and Development, United Kingdom

Early pregnancy, food insecurity, enlistment into paid and unpaid work for household subsistence can increase the vulnerability of rural adolescents and have adverse effect on their nutrition and health through unmet energy needs. As a result of rural transformation, the lifestyles of adolescents are changing in terms of the types of activities they undertake and how they allocate their time – towards less energy-intensive activities. This change is in addition to the evolving trend towards increasing consumption of ultra-processed foods. But the effects of these adjustments in food insecure contexts is unclear. The implication of this knowledge gap is the absence of data to guide interventions aiming to protect young people against all forms of malnutrition. This study assesses physical activity, time use and diet in relation to nutritional outcomes for adolescents in India and Nepal. We use quantile regression in compositional data analysis methods – to assess the relationship between nutritional outcomes and the composition of daily time allocated to sedentary, light, moderate and vigorous activity. In addition, we assess the relationship of nutritional outcomes with the composition of diet involving ultra-processed and non-ultra-processed foods. The situation that adolescents in developing countries are facing is that of increasing sedentary lifestyles through technology and infrastructures. Although these are avenues where physical activity is reducing, results shows that there is still substantial physical labour under which adolescents continue to perform. The substitution of non-ultra-processed food by ultra-processed food improves energy adequacy but likely presents a burden of unhealthy diet. That physical activity and diet effect varies across the spectrum of nutrition status implies that addressing malnutrition among rural adolescents will require different kinds of interventions – some targeted at the lower ends of the nutrition status and a different set for the upper end of the nutrition status. Nutrition interventions providing food support should be encouraged to sustainably reduce undernutrition through the provision of energy and nutrient adequate food items. In addition to interventions, nutrition transition may also present a useful contribution to nutritional outcomes and this knowledge should guide the type of food items distributed or subsidised to rural households.

Keywords: Adolescents, India and Nepal, nutrition transition, nutritional outcomes, compositional data analysis methods, time use, physical activity

Contact Address: Oluwatosin Aderanti, University of Reading, School of Agriculture, Policy and Development, Whiteknight Campus, Reading, United Kingdom, e-mail: o.aderanti@pgr.reading.ac.uk

Preserving food environments and livelihoods: Transitions and challenges for the Ca Dong people in Vietnam

Kien Dang[1], Thi Thu Giang Luu[2], Simone Kathrin Kriesemer[3], Hung Pham-Van[4], Hoa Bui Thi Khanh[4], Dung Pham-Van[1], Eike Luedeling[2], Cory Whitney[2]

[1]*Social Policy Ecology Research Institute (SPERI), Research and Development and Policy Advocacy, Vietnam*

[2]*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany*

[3]*University of Bonn, Center for Development Research (ZEF), Germany*

[4]*Vietnam National University of Agriculture (VNUA), Vietnam*

The food environments of the Ca Dong people have changed dramatically since they were resettled from ancestral lands for the construction of the Dak Drinh hydropower reservoir in 2013. Food environments have shifted from traditional hunting, wild harvesting, and swidden agriculture, to low-income commodity production, leading to a decline in forests and the loss of traditional food plants and animals. Through transdisciplinary approaches, we engaged eight groups of stakeholders including local party leaders and forest-dependent communities to explore options for supporting diverse and sustainable food environments. We report on the participatory exploration of forest food availability and diversity, and the potential of reforested areas to restore traditional food environment practices. We use satellite image analysis (http://rung-ray-ruong.org/) to assess policy-level land-use planning to understand the transitions from forests to farmlands and their implications for food environments and forest ecology. Expected changes follow an environmental Kuznets curve - conversion of diverse forests to monoculture commodity production has resulted in a loss of ecological resources as well as traditional ecological knowledge and customarily governed forest harvests, affecting food choices and livelihoods - the future of these complex forest systems is unclear. The intertwined issues of forests, food environments, poverty, cultural preservation, and sustainable resource protection highlight the complex challenges faced by indigenous communities undergoing resettlement and changes in their food systems. Together we set out to identify and model possible solutions, including agroforestry interventions in productive zones. However, to be a realistic alternative, these interventions need to provide equivalent income to cassava planting (roughly 20 million VND per ha/yr). Our work aims to contribute to the understanding of these challenges

Contact Address: Cory Whitney, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Science, Auf Dem Hügel 6, 53111 Bonn, Germany, e-mail: whitney.cory@gmail.com

and develop evidence-based solutions that balance economic development with ecological and cultural sustainability. By collaborating with local stakeholders and incorporating local ecological knowledge, we hope to support interventions for sustainable diets, biodiversity conservation, and livelihood security in the changing landscapes of Vietnam's highlands. As we further identify and describe forest foods, the next phase of the work will be to test selected species for nutrition and field sites for the potential of growing in homegardens.

Keywords: Agroforestry, environmental Kuznets curve, evidence-based solutions, food environment, homegardens, sustainable food, transdisciplinary research, Vietnam

Linking seed accessibility to nutrition using structural equation modelling approach: The case of ethnic minority in northern Vietnam

Nguyen Lan[1], Marrit van den Berg[1], TjeerdJan Stomph[2]

[1]*Wageningen University and Research, Development Economics, The Netherlands*
[2]*Wageningen University and Research, Plant Sciences, The Netherlands*

Ethnic minorities in Vietnam face chronic under-nutrition issues, potentially worsening the situation due to the COVID-19 pandemic. Agriculture offers a logical entry point to offer the vulnerable groups a diversified diet to cope with micronutrient deficiency. Therefore, numerous studies have explored the linkages between crop diversification to diet. However, the role of seed accessibility in the framework has not yet been studied, even though it is the prerequisite of any agriculture farming system. This study investigates how seed accessibility links to diet diversity via two key pathways, from direct consumption of farm-level crop diversity or market purchase. We covered crop diversity, output, food market access, and women's time use as the mediators in the framework. Our study sites were two districts Sapa and Mai Son, located in Northern Vietnam, which differ in physio-climatic conditions. We used data from 600 farmer surveys, 38 community surveys, and 54 seed vendor surveys which were collected from December 2021 to July 2022. We focused on vegetables and legumes, especially three nutrition-sensitive food groups: dark green leafy vegetables, legumes, and other vitamin A-rich vegetables. Crop diversity and diet diversity were measured by the number of key food groups grown or consumed. Diet diversity data were collected by 24h and 7-day diet recall methods. Women's time use was time and activity diary in the past 24h. Seed accessibility was an index measured at the community level, which indicates the distance from the village to all seed sources available in the district, seed types diversity available in the source, and average perceived quality. The seed sources include self-saving and the seed subsidy programme in the region. Data were analysed through the structural equation modelling method (SEM). Preliminary findings found that seed accessibility does not significantly link with crop diversity. However, crop diversity closely links with diet diversity through the subsistence pathway. Women's time use is the mediator in the framework, which associates with both crop and diet. The framework is highly contextually dependent as it only works in Sapa but not in Mai Son.

Keywords: Crop diversity, diet diversity, ethnic minority, seed accessibility

Beyond diet: Assessing the physical activity dimensions to combat malnutrition in Tanzania

Msabila Damian Charles[1], Martin Grauduszus[2], Nina Ferrari[3], Christine Joisten[2], Jonas Tiboroha[1], Constance Rybak[4], David Friesen[2]

[1]*University of Dar es Salaam, Dept. of Physical Education and Sport Sciences, Tanzania*
[2]*German Sport University Cologne, Dept. of Physical Activity in Public Health, Germany*
[3]*University Hospital Cologne, Cologne Centre for Prevention in Childhood and Youth / Heart Centre Cologne, Germany*
[4]*Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany*

The "triple burden of malnutrition" - undernutrition, overnutrition or obesity, and micronutrient deficiency - is one of the growing challenges in sub-Saharan Africa. This nutrition transition is caused by changes in lifestyle and dietary patterns, being influenced by urbanisation, globalisation and economic development. Although the reasons for malnutrition are diverse, several strategies for prevention have been developed. Optimisation strategies for improved nutrition include e.g. dietary diversification and nutrition education measurements; however, healthy food environments and physical activity (PA) promotion are key elements of preventing malnutrition. The transdisciplinary FoCo-Active project aims to modify food consumption and PA behaviour including the implementation of a health literacy programme to combat all forms of malnutrition in rural and urban Tanzania. The aim of this analysis is to assess the physical activity dimension by analysing the level of PA in Tanzania females and males. Within the FoCo-Active project, a cross-sectional study was conducted with a sample size of n=521 (372 females, 149 males), age (M=35.8, SD=7.9 females and M=39.8, SD=10.3 males) from urban (Dar es Salaam) and 194 (115 females, 79 males), age (M=38.3, SD=10.4 females and M=44.8, SD=13.6 males) from rural (Mkuranga). Target groups responded to the Global Physical Activity Questionnaire (GPAQ) to provide information on their PA status. Results indicated that rural participants were involved more hours per week in vigorous-intensity PA at work (M=24.2, SD=14.8) than the urban participants (M=14.9, SD=17.0) and less hours per week in moderate–intensity PA (M=13.5, SD=9 than urban participants (M=21.5, SD=18.8; $p < 0.001$). Furthermore, findings show that urban participants spent more hours in vigorous-intensity sports, fitness and recreational (M=5.3, SD=7.6) compared to rural participants (M=3.2, SD=2.6; $p > 0.005$). Although both groups in the rural and urban areas met the WHO's PA recommendations (75 [vigorous-intensity] or 150 [moderate–intensity] minutes per week), urban participants spent more time in vigorous-intensity PA within their leisure time than rural participants in Tanzania. The PA environment should be assessed in future studies to identify possible approaches to PA promotion for both groups to combat all forms of malnutrition.

Keywords: Health literacy, malnutrition, physical activity

Contact Address: Msabila Damian Charles, University of Dar es Salaam, Dept. of Physical Education and Sport Sciences, Dar es Salaam, Tanzania, e-mail: msabila.charles@yahoo.com

Co-developing nutritious foods with societal actors to improve child nutrition in northern Benin drylands

Adrien Dogo, Franck Hongbete

University of Parakou, Foods Sciences Laboratory, Benin

Malnutrition is a persistent and increasing issue in the drylands of Africa. The new global challenges of COVID-19 and climate change are significantly impacting the livelihoods and increasing the vulnerability of the region. However, nutritious foods developed by researchers from traditional food products have received little interest from the population. The objective of this study is to identify the extent to which it is possible to co-develop nutritious, healthy, affordable, and desirable foods from interest traditional foods products for societal actors. To achieve this, we organised focus group discussions (n=4) with mothers and local processors to select foods of interest, diagnose current food processing technologies, and identify local options and resources for improving the nutritional and sensory qualities of foods. We used the Solver linear programming function in Excel to formulate the foods. Two joint co-development sessions were organised with local processors to test the identified lower-cost formulations. The results demonstrate that the co-developed feeds can cover at least 50 %, 50 %, 83 %, and 35 % of the iron, zinc, protein, and vitamin C requirements, respectively, for 6–12 months old children per 100g. The cost analysis shows that for a 100g portion, all foods are affordable in relation to the daily food expenditure capacity of individuals in the study area. This study has demonstrated that it is possible to co-develop affordable and nutritious foods with societal actors to combat malnutrition. As co-development incorporates the knowledge of societal actors, this approach could be scaled up in the fight against malnutrition by improving the desirability and adoption of nutritious foods developed from local food products.

Keywords: Co-development, drylands areas, malnutrition, nutritious foods, traditional food products

Contact Address: Adrien Dogo, University of Parakou, Foods Sciences Laboratory, Banikanni maison agonssaclounou, Parakou, Benin, e-mail: adriendogo@gmail.com

Role of food choice motives in socioeconomic disparities in food consumption and nutritional outcomes

Cecilia Maina

University of Bonn, Center for Development Research (ZEF), Germany

The rise of overweight and obesity prevalence in sub-Saharan Africa is concerning due to the increased risk of non-communicable diseases. Poor diets from unhealthy food systems are the primary cause, driven by income growth, urbanisation, and technological change. Multinational food industries have played a role in this shift, by manufacturing, distributing, and promoting highly processed foods that have a strong sensory appeal. These foods are usually high in fats and sugars as these components contribute to the taste, texture, and overall enjoyment of the food. Income and education create variations in dietary behaviours and weight outcomes among different socioeconomic groups. As income rises, individuals have greater resources to purchase diverse foods and consume more calories, leading to overweight and obesity prevalence. Consumer behaviour also plays a key role in the variations seen in food consumption patterns and weight outcomes. The paper's main aim is to understand the role of food choice motives in explaining differences in diet diversity, and weight outcomes among different socio-economic groups in Kenya.

Data used for this study sampled participants from 4 counties in Kenya to collect socioeconomic, food consumption, and anthropometric data. Food choice motives were collected using the food choice questionnaire. The data was collected in 2022 and comprised 381 men and women above the age of 18. Mediation analysis was conducted using the Karlson-Holm-Breen method for linear and non-linear probability models. Empirical results show that the probability of an overweight and obese BMI level increases by 19 % for a standard deviation change in the asset score and by 8 % for a standard deviation change in years of schooling. These relationships were significantly mediated by sensory motives. Sensory motives explained 28.97 % of the wealth-BMI association and 29.50 % of the education-BMI relationship. Higher education was associated with increased diet diversity mediated by higher health and sensory concerns.

Findings suggest that higher sensory motives are driving the prevalence of overweight and obesity among high socioeconomic groups. Strategies should be geared towards restricting the marketing of energy-dense foods, implementing sugar taxes to deter consumption, and other nudge policies to curb the growing burden of overweight and obesity.

Keywords: Diet diversity, food choice motives, non-communicable diseases, overweight and obesity, socioeconomic disparities

Contact Address: Cecilia Maina, University of Bonn, Center for Development Research (ZEF), Bonn, Germany, e-mail: cecilia.cmaina@gmail.com

ID 453

Schools food environments in Boukombe and Natitingou and students' perceptions about these environments

Mélina Houndolo[1], Sam Bodjrenou[2], Malikath Bankole[1], Irmgard Jordan[2], Céline Termote[2], Waliou Amoussa Hounkpatin[1]

[1]*University of Abomey Calavi, Faculty of Agronomic Sciences, Benin*
[2]*The Alliance of Bioversity International and CIAT, Food Environment and Consumer Behaviour, Benin*

The food environment is recognised as having a strong influence on the eating habits of individuals. At adolescents' level, school-based nutrition interventions are an important framework for examining environmental strategies to improve healthy food choices among youth, particularly with the intake of fruits and vegetables. This study aimed to analyse the food environment of main colleges of Boukombe and Natitingou, which are situated in high food insecure communes in North-Benin, and the college students' perceptions about these environments. All outlets and fruit trees publicly accessible within one-kilometer radius of the schools were mapped. An inventory of the outlets was added. Individual interviews were conducted with 300 students using a perception questionnaire. Overall, 96 outlets and 32 fruits trees were geocoded in Boukombe. The inventory showed that vegetables (20.5 %), cereals (13.9 %) and dried fish (9.9 %) were the most represented food groups on offer. Fruits were available in only 7.3 % of outlets. Mango trees are the most represented (65.6 %). The perception of the students indicated that, it is difficult to find healthy fruits and vegetables around their college (82.4 %), and that fruits and vegetables are expensive (72.6 %). Natitingou college food environment was composed of 61 food outlets and 17 fruits trees. The most important food groups on sale were cereals (23.8 %), vegetables (13.4 %) and sugar products (10.5 %). Mangoes are the main fruit trees (58.8 %). Here, 58.5 % of students thought that it is easy to buy fruits and vegetable in their environment and 53.5 % that they have a large choice/diversity of fruits and vegetables. In the other hand, 41.5 % thought that fruits and vegetables are expensive. All students at both colleges consumed mango when its season come and thought that it is the most available and accessible during this period. Most fruits available on the food outlets are imported. The school food environment in both Natitingou and Boukombe communes is a real challenge especially regarding diversity and financial accessibility of fruits and vegetables. Thus, it is important to take actions such as implementation of school gardens to improve the availability and accessibility of fruits and vegetables for students.

Keywords: Benin, food choice, food outlet, fruit trees, fruits and vegetables, students

Contact Address: Mélina Houndolo, University of Abomey Calavi, Faculty of Agronomic Sciences, Womey, Calavi, Benin, e-mail: reenmelh@gmail.com

Towards a local system for screening child malnutrition

Chérif Issifou[1], Bourama Guindo[1], Irène Médémè Mitchodigni[1], Brigitte Kaufmann[2], Waliou Amoussa Hounkpatin[1]

[1]*University of Abomey-Calavi, Fac. of Agricultural Sciences, Benin*
[2]*German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*

As the first in charge of the child's health and nutrition, mothers have their own method for detecting malnutrition in children. However, this local method and how it is used are unknown. The aim of this study was to describe the local method used by caregivers in northern Benin to assess the nutritional status of their children. A co-inquiry with caregivers from three different ethnic groups was conducted in five stages between March and June 2022, involving focus group discussions and joint assessments. The recordings of the interviews were transcribed and then content analysed using MAXQDA software. The "Baatonu", and "Fulani" caregivers identified two categories of malnutrition: "Poutankou" and "Peouri Danéri" for "less severe malnutrition", and "Tikpirou", and "Peouri" for "severe malnutrition". The "Gando" cargivers identified three categories: "Peouri Gon'an/Kouri kawê" for "less severe malnutrition", "Peouri Takinori" for "moderately severe malnutrition", and "Peouri Foroua/Tikpiroua" for "severe malnutrition". These different categories of malnutrition are defined by different signs/symptoms, of which the following five (5) are common to all ethnic groups: "weight loss", "pale eyes", "child not eating well", "child eating sand or clay", and "oedema of cheeks and feet". Screening for malnutrition is done through a series of decisions based on the presence or absence of the signs/symptoms. Gando's caregivers' method of assessing nutritional status, use more signs/symptoms than others. These local methods of assessing nutritional status have similarities, reflecting local expertise, and differences that can be used to improve each method through mutual learning. This could be a starting point for setting up a reliable maternal malnutrition screening system that can be integrated into the current community-based nutrition surveillance system.

Keywords: Children, local method, northern Benin, nutritional status, signs, symptoms

ID 744

Public policies, governance and institutions

Governance and (bio)economic aspects of food systems transformation

The state of urban food policy action in emerging Asia

Miriam E. Romero Antonio[1], Steve Jaffee[2], Navneet Kumar[1]

[1]University of Bonn, Center for Development Research (ZEF), Dept. of Economic and Technological Change, Germany

[2]University of Maryland, Dept. of Agricultural and Resource Economics, United States

While the important role of cities in food system transformation has long been understood, there is a more recent recognition that food-related outcomes also have an important influence on how well cities can achieve their own broad socio-economic and other aspirations. This recognition has led many cities, around the world, to engage more actively in food policies and programs. The literature documenting this experience is largely case study-based and primarily covers actions and outcomes in larger cities. We analyse the overall state of urban food policy across Asia, drawing attention to distinctive patterns across city size categories and testing hypotheses which may explain the diversity of observed patterns of food policy engagement. Particular attention is given to demographic, institutional, and geographical factors which have likely influenced either the motivation or the capacities of cities to act on food matters. We find that most Asian cities are at an early stage in efforts to apply coherent and coordinated approaches to address food-related challenges and opportunities. The opportunities for future economic gain and avoidance of social costs may be greatest among the region's fast-growing small- and medium-sized cities, yet many such cities lack the requisite capacities to influence complex food system matters and will require assistance from national agencies and others. The research community also has an important role to play, addressing knowledge gaps and emerging trends related to the structure and performance of urban food systems, patterns of consumer behaviour, and the incidence of food-related risks, further assessing the drivers influencing urban food policy interventions, evaluating the effectiveness and impacts of urban food policies and programs, and drawing attention to emerging good practices which other cities might adopt or adapt to their circumstances. Both case studies and multi-city surveys will be valuable in such endeavours.

Keywords: Asia, benchmarking, cities, food smart, food systems, urban food policy

Contact Address: Miriam E. Romero Antonio, University of Bonn, Center for Development Research (ZEF), Dept. of Economic and Technological Change, Genscherallee 3, D-53113 Bonn, Germany, e-mail: mromeroa@uni-bonn.de

Trade-offs and synergies amongst competing pathways for sustainable agricultural transformation in Africa

Marcus Giese[1], Juliet Kariuki[1], Lutta Alphayo[2], Maria Oguche[1], Katrin Winkler[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*

[2]*University of Nairobi, Kenya*

Challenges facing agriculture are pervasive. Land, water and soil degradation, climate change and biodiversity losses are of global concern especially because their impacts are always unequally distributed. The interactions between these challenges have given rise to paradigm shifts in support of integrated approaches for achieving sustainable and resilient food systems. However, ongoing debate abounds regarding how to increase productivity while minimising trade-offs that undermine the natural and socio-economic resources required for agriculture to survive and thrive. In Africa, increasing population and changing consumption patterns have led to growing food and land demands. Consequently, the continent is witnessing the emergence, permanence and disappearance of competing concepts to address the difficulties facing agricultural production. It is within this context of contestation that the DAAD Agriculture Alumni Training Network organised travelling workshops in Kenya and Germany. The focus was on highly topical issues, namely, 'Paradigm shifts in Agricultural Systems towards Sustainable Land-use'; 'Integrating Systems for Sustainable Agricultural Transformation' and 'Tradition meets digitalisation – a new dream team for sustainable land use?'. The aim was to explore and analyse the complementarities and constraints of adopting competing concepts from the perspective of various stakeholders. There was merit in applying integrated vis a vis conventional approaches, such as agroecology which increased biodiversity and, in some instances, agricultural productivity. The adoption of digital approaches was considered promising particularly for monitoring soil health and seasonal forecasting. The combination of indigenous knowledge for crop and livestock production was deemed ideal for ensuring that social and agricultural outcomes were equitably met. This was, especially with respect to holistic rangeland management which exhibited synergies between livestock production, wildlife, and humans. However, trade-offs were associated with the increased labour required to adopt agroecological approaches, the resource-based conflicts related to planned grazing management with cultural landscapes, especially during periods of drought and in some instances, the neglect of animal welfare with respect to meeting

Contact Address: Juliet Kariuki, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: j.kariuki@uni-hohenheim.de

increased local demand for meat products. Overall, the outcomes of applying integrated approaches whilst minimising trade-offs were shaped by barriers often beyond the farm, therefore complimentary institutional efforts across scales to enhance synergies and build systemwide resilience are required.

Keywords: Agroecology, paradigm shifts, synergies, trade-offs

Governance challenges and digital tools in smallholder agricultural carbon projects: Insights from Kenya

Vida Mantey[1], Christine Bosch[1], Athena Birkenberg[1], Regina Birner[1], John Mburu[2]

[1]University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

[2]University of Nairobi, Dept. of Agricultural Economics, Kenya

The generation of carbon certificates through specific farming practices is increasingly used as a mechanism for climate change mitigation. Recently, such carbon projects pooled thousands of smallholder farmers from developing countries to enable them to take part in the voluntary carbon market and receive benefits from carbon credit sales. However, there is very little knowledge on potential governance challenges that might hinder the effective implementation of such large and complex projects, where many different actors such as project developers, verifiers, investors, and donors interact and hold different interests and power relations. Meanwhile, despite numerous studies that unveiled the potential of digital tools in addressing such challenges in other sub-sectors of agriculture, it has not yet been explored in implementing smallholder agricultural carbon projects. This paper employs a qualitative case study of two carbon projects in Kenya, and a participatory and visual mapping tool (Process Net-Map) with stakeholders, to identify the governance challenges arising from the roles, interactions, and power relations of different actors, and the potential of digital tools to address such challenges. Our results show a diverse number of governance challenges at different levels of such projects that have an impact on the adoption of recommended farming practices, carbon monitoring accuracy, and efficiency. Furthermore, power relations between actors reveal deficiencies in the inclusiveness of such projects. Strategies used in resolving some of the challenges include holding and reinvesting carbon revenues at the group level, emphases on co-benefits, and the application of simple digital tools. Based on these results, we recommend the development of local-level capacity to use digital tools to collect and analyse data, reframing the prospects of carbon farming, and development of government schemes that reward participants, to increase the efficiency of carbon projects and the benefits generated for smallholders.

Keywords: Carbon certificate, digital tools, governance challenges, Kenya, process net-map, smallholder carbon project

On the feasibility of an agricultural revolution: Sri Lanka's move to go one-hundred per cent organic

Pay Drechsel, Piumi Madhuwanthi, Duleesha Nisansala, Dushiya Ramamoorthi, Thilini Bandara

International Water Management Institute (IWMI), Circular Economy, Sri Lanka

In April 2021, the Sri Lankan Government announced a ban on importation of agrochemicals including chemical fertilisers to make Sri Lanka the first country in the world to go fully organic and be free of chemical fertilisers.

Going "organic" was not a novel approach since there were several attempts over the years to support organic farming in the country. The National Agricultural Policy of 2007 recommended increasing the usage of local organic fertilisers gradually, like from January 2021 by up to 30 % within a 3-year period. While such a step-wise transition has obvious advantages, the announced immediate ban took the sector by surprise, but was 'supported' by the emerging economic crisis the country faced with declining foreign exchange reserves to import chemical fertilisers. As described by the President, the motive for the ban was however to reduce the impact caused by agrochemicals on environment and human health, including the common cases of kidney failure in some parts of the island. This could be considered a visionary (pre-emptive) move as clear scientific evidence for such a link is missing so far.

Without any transitional time, a run for 'organic fertiliser' started but could not satisfy demand on short notice resulting in severe agricultural losses, e.g., in the important paddy and (export) plantation sectors. Under growing protests, the Government eventually lifted the chemical fertiliser ban via a gazette notification on 1st December 2021.

The failed ban posed a range of questions related to transformative processes, in particular on the best institutional pathways for such a drastic transition, and possible alternatives. But also questions on the reasoning were posed and on the actual feasibility of such a change.

This presentation will shed light on the feasibility of such a transition in terms of the actual and potential availability of biomass (i.e., crop nutrients) to 're-place' chemical fertilisers at national scale, also under consideration of regional variations in demand and supply. The focus will be on paddy rice and the plantation sector, resulting in recommendations for any repetition of such a transition in the future, in Sri Lanka, or elsewhere.

Keywords: Agricultural transformation, biomass, chemical fertiliser ban, organic farming, Sri Lanka

Contact Address: Pay Drechsel, International Water Management Institute (IWMI), Circular Economy, P.O. Box 2075, Colombo, Sri Lanka, e-mail: p.drechsel@cgiar.org

ID 133

Access to agricultural land for Uruguayan youth and the role of the national institute INC

MELINA GRIFFIN[1], INGRID FROMM[1], JORGE ALVAREZ[2]

[1]*Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), Switzerland*

[2]*University of the Republic Uruguay, Dept. of Social Sciences, Faculty of Agronomy, Uruguay*

Globally, the farming sector is facing the problem of overageing. Youth that are interested in the farming sector are often lacking starting capital, which constrains them from earning a livelihood in the sector. This is also the case in Uruguay, where the National Colonisation Institute (INC) helps individuals accessing land, with a special focus on young people. The INC rents out fractions for half the market price, offering an attractive option for youth.

This case study higlights the challenges of youth (≤ 35 years) accessing land in Uruguay and the criteria according to which the INC selects applicants. Furthermore, the work evaluates whether the INC plays a role in countering landgrabbing in Uruguay and whether the INC model could be applied in other countries as well.

Wanting to capture individual experiences and opinions in detail, a qualitative research approach was chosen. Six young people that all had faced difficulties accessing land were visited on their farms in Uruguay and semi-structured interviews were carried out. Semi-structured interviews were also realised with staff of the INC as well as key experts on the topics of landgrabbing, youth, and access to land. The secondary data collection was complemented with a literature study.

Findings suggest that the evaluation criteria of the aspirants must be revised because there are contradictions within the evaluation scheme. On top of that, inconcistencies in the interviews and inappropriate assumptions show that the interviews with the aspirants are not always carried out in a professional manner. Having a mission of providing access to land for smallholder family farmers, the INC is not a suitable tool to fight landgrabbing and on top of that only covers 3 % of the country's agricultural surface. However, because all land with a certain quality first must be offered to the INC at market price, it can help with price transparency on Uruguay's land market.

The INC model is certainly interesting to be replicated in other countries. Certain adaptations to the country-specific circumstances will have to be made.

Keywords: Access to land, INC, land tenure, smallholder farmers, Uruguay, young farmers

Contact Address: Melina Griffin, Bern University of Applied Sciences (BFH), School of Agricultural, Forest and Food Sciences (HAFL), Kuehrainweg 3, 4805 Brittnau, Switzerland, e-mail: melina.griffin@gmx.net

Unraveling governance challenges in the provision of extension services for smallholder agricultural carbon projects: Evidence from western Kenya

Manuel Díaz, Christine Bosch, Athena Birkenberg, Fiona Hasenbach, Regina Birner

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Development projects aimed at increasing Soil Organic Carbon (SOC) stocks in agricultural soils are considered one of the great opportunities opened up by the Clean Development Mechanisms. Carbon projects promote Sustainable Agricultural Land Management practices in order to increase SOC and sell carbon certificates on voluntary markets. With the revenues obtained, projects attempt to 1) finance the set-up and maintenance costs (mainly monitoring), and 2) support farmers either by direct payments or by financing agricultural extension services. However, carbon projects often face implementation challenges such as the duplication of services or other uncoordinated actions. In order to increase the understanding of possible governance challenges of carbon projects and identify some tools to address them, this study aims to analyse the landscape of extension actors around the Western Kenya Carbon Project by combining a theoretical framework for the evaluation of extension and monitoring services with the concepts of the New Institutional Economics. Two qualitative empirical methods were applied to collect data; a participatory mapping technique known as Net-Map and expert/key informant interviews involving a broad set of stakeholders. The findings highlight elements that may compromise the effectiveness of extension services, such as the presence of other initiatives with interests that are either 1) in opposition to the Prosoil project (e.g., promoting subsidies for chemical fertilisers and/or pesticides) or 2) aligned with those of the project, preventing proper measurement of extension impact as farmers may adopt practices and technologies due to a contagion effect. In addition, the short period of training granted to producers given the high number of farmers targeted by the project, may generate additional governance challenges related to the reduction of SOC storage, as extensionists must move from one farmer group to another in order to cover the target farmers while reducing the support required to ensure long-term SOC sequestration. Project managers will be better prepared to offer extension services in upcoming agricultural carbon projects by recognising these difficulties, particularly by understanding how crucial the institutional environment is for fostering collaboration among initiatives and develop strategies to support farmers and minimise SOC loss.

Keywords: Africa, carbon markets, development projects, extension services, soil carbon

ID 527

International genebanks at risk: Hazard assessment and consequences for risk management

Theresa Herbold

University of Hohenheim, Germany

Genebanks are essential for safeguarding global crop diversity whereby international and supranational genebanks play a crucial role. Despite the growing worldwide awareness of this, it is often overlooked that genebanks are subject to several challenges and risks which might jeopardise their physical integrity. Past incidents and events resulting in the partial loss of important crop collections or even entire genebanks have drastically shown this. A recent example is the ICARDA genebank, originally located in Aleppo, Syria. Being at risk of losing its germplasm collections as a consequence of the Syrian civil war, the genebank had to be relocated in 2016 to Lebanon and Morocco. Parts of the collection could only be restored with safety duplicates preserved at the Svalbard Global Seed Vault (SGSV) and other international genebanks. Presently a scientific basis for identifying, assessing and managing risks at genebank level is still lacking. The Master's thesis "Hazard assessment and risk management of national and international genebanks for a sustainable conservation of plant genetic resources" - submitted to the University of Hohenheim in 2022 - aims to address this research gap by providing a risk analysis for three key risk groups: natural hazards, political risks, and financial risks. It was carried out for a sample of 80 important supranational and national genebanks comprising at least 4.78 million accessions or roughly 65 % of the total conserved accessions worldwide. A mix of methods was applied, including a literature review, quantitative exposure assessments and expert interviews. The risk assessment tool of Munich Re "Natural Hazards Edition" allowed a location specific comparison of the natural hazard exposure.

The focus of the presentation will be on the 14 international and regional genebanks – most of them managed by the CGIAR centres. Results show that genebanks in the Asia-Pacific region are most exposed to natural hazards, while institutions in African and some Asian countries are rather vulnerable to political risks. Based on this assessment, risk management strategies, including risk mitigation and transfer solutions, will be presented.

Keywords: *Ex situ* conservation, genebanks, hazard assessment, risk management

COVID-19 lockdown in south-east Nigeria: Evidence-based findings to support need for food systems transformation

Johnny Ogunji[1], Chinwe Ogunji[2], Stanley Iheanacho[1], Michael Olaolu[3]

[1]*Alex Ekwueme Federal University Ndufu-Alike, Fisheries and Aquaculture, Nigeria*
[2]*Alex-Ekwueme Federal University Ndufu-Alike, Educational Foundations, Nigeria*
[3]*Alex-Ekwueme Federal University Ndufu-Alike, Agriculture, Nigeria*

Outbreak of the novel coronavirus disease (COVID-19) late 2019 brought the whole world to a state of pandemonium. The infection was declared as a pandemic by World Health Organisation in March 2020. As a way to curtail the rate of infection, countries imposed lockdown. Unfortunately the lockdown bolstered the problem which the infection has already caused. Economic activities became stranded, lives, livelihoods and hunger exponentially elevated in the society. Low- and middle-income countries like Nigeria was highly affected. The data collated during a survey of 1209 households (urban and rural locations) in five states of South-East Nigeria during the COVID-19 lockdown is laying credence to the importance of food systems transformation. Radimer/Cornel hunger scale was used to determine the Household hunger. Chi-square test was done to confirm the significance ($p < 0.05$). The study revealed that in Abia State, the prevalence of hunger among households before COVID-19 pandemic was 99.6 %, while during COVID-19 lockdown, hunger prevalence rose to 100 %. On the other hand the prevalence of hunger among households before COVID-19 pandemic in Enugu State was 31.8 %, while during COVID-19 lockdown, hunger prevalence rose to 99.6 %. The situation in Abia and Anambra States shows that there were no much changes in the household hunger situation as only 0.4 % change was observed. In Enugu State it is note-worthy that the observed change was 67.8 %. It was also observed that covid-19 lockdown significantly affected food prices. More than 90 % of respondents confirmed that food was more expensive during the lockdown. Unfortunately, hunger situation was bad before the COVID-19. This can be related to lack of food and poor food systems. On the premise that food systems involve production, processing, distribution, and consumption, this study observes that transforming food systems in South East Nigeria is inevitable.

Keywords: Covid-19, food systems, hunger prevalence, lockdown, South-East Nigeria

Contact Address: Johnny Ogunji, Alex Ekwueme Federal University Ndufu-Alike, Fisheries and Aquaculture, PMB 1010 Abakaliki, Nigeria, e-mail: ogunjijo@yahoo.com

ID 297

An analysis of the European regulatory status of selected non-timber forest products from the Brazilian Cerrado

Dominic Baron, Dietrich Darr, Kathrin Meinhold

Rhine-Waal University of Applied Sciences, Fac. of Life Sciences, Germany

Non-timber forest products (NTFPs) are not clearly defined, they are often referred to as a product or service other than timber that originates from forests. This for example includes fruits, nuts, herbs, and medicinal plants. With an increased demand of NTFPs from Europe and the United States of America, the marketing of these niche products has gained attention. In this context, the concept of NTFP governance has evolved which consists of different aspects like institutional arrangements, norms, and collective social practices. This overall development led to an increase in national and international regulations concerned with product quality and production systems around NTFPs. As a result, a very complex framework which contains numerous policy domains like agriculture and forestry as well as food safety and trade arose. Additionally, it involves various stakeholders including for example, harvesters, processors, and policy makers operating on diverse geographical levels (local, national, European, and international).

This thesis analyses the European regulatory status of five selected NTFPs from the Brazilian Cerrado. It is the aim to analyze whether the current legal frameworks of the EU enable the import of selected Cerrado NTFPs into the European market. Not only was a literature research done, but also multiple interviews with researchers were conducted. The results of this study indicate that the current regulatory framework prevents the development of value chains for NTFPs due to their complexity. Especially the European novel food regulation hinders the import of NTFPs into the European Union. It must be considered that further research is needed on analysis of the value chains, international regulatory framework and monitoring and reporting of NTFPs. In further research emphasis on the producer side shall be placed.

Keywords: Agriculture, Brazil, food supplements, forestry, governance, non timber forest products, policies

Contact Address: Dominic Baron, Rhine-Waal University of Applied Sciences, Fac. of Life Sciences, Rudolf-Virchow-Straße 16, 16225 Eberswalde, Germany, e-mail: dominic-baron@hotmail.de

Analysing policy attributes for promoting solar powered irrigation systems in Karnataka, India

Aditya Korekallu Srinivasa, Dagmar Mithöfer

Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany

Solar Powered Irrigation Systems (SPIS) is an important component of India's effort towards sustainable energy transition in agriculture. SPIS can positively contribute in improving both access to water and in reducing the dependence on centralised electricity supply which is primarily coal based. SPIS is also promoted at the policy level with substantial funding support envisaged under PM -KUSUM program. In spite of the promise and the policy push, the adoption of SPIS under PM – KUSUM is low. Farmers' preference for policy attributes related SPIS is not well understood, which could help realigning the policy. In this paper, we use Choice Experiment (CE) for evaluating the policy attributes in promotion of SPIS as it can provide rich policy information in terms of welfare implication of the policy (in terms of willingness to pay) and disaggregate it by attributes. The attributes and levels were selected based on extensive review of literature, and interview with farmers and experts. Upfront cost, terms of loan, service provision, multiple uses and grid connections were the five attributes with different levels. A 'D-efficient' experimental design was used to generate 32 choice cards with 3 alternatives in each card (including opt-out), which were then randomly distributed into four blocks with eight cards each to reduce the cognitive load on the respondents. A pilot survey of 12 farmers were used to obtain the priors (coefficients for each attribute) to eliminate choice sets with dominant alternatives. The data was collected from 500 farmers randomly chosen from 31 villages across Mysore district, Karnataka, India. The data was analysed using the random parameter logit model allowing for heterogeneity in estimation of farmers' preferences for SPIS. The results indicate that farmers' preference as indicated by highest part worth is for guaranteed service provision for 10 years and loan with repayment holiday of three years. Given that SPIS is a new technology with a high initial investment, assuring farmers with guaranteed repair service act as a strong incentive to adopt. For increasing the adoption of SPIS, these attributes can be incorporated into the existing policies so that they align well with farmers' preferences.

Keywords: Discrete choice experiment, sustainable energy transition

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ID 555

Financial needs of farmers in Benin and how financial institutions try to respond to them

Karin Gaesing

University of Duisburg-Essen, Inst. for Development and Peace (INEF), Germany

In Benin, poverty and food insecurity are still mainly a rural phenomenon with a poverty rate of 44,2 % in rural areas vs. 31,4 % in urban areas. Generally, farm productivity is low. Smallholder farmers often lack the financial resources to invest in their farms to increase productivity. They lack the resources to mechanise, diversify or increase their production or irrigate their fields. They do not have the money, labour and inputs for it. The offers of banks and micro-finance institutions on the other hand are not always adapted to farmers' needs.

A team from INEF, University of Duisburg-Essen, analysed the needs and constraints of male and female farmers to invest in their farms in 24 communities in six Départements of the country. They looked into savings opportunities, investment preferences, risk avoidance, strategies to manage the repayment as well as the credit benefits of farmers. At the same time, the team looked into the offers of financial institutions regarding agriculture and the relations between farmers and financial institutions, which are quite often characterised by ignorance and mistrust.

The possibility to receive credits for agriculture does not only provide a huge potential for farmers to increase their yields and thus their income, but can also put them into the trap of repayment pressure and indebtedness. In case of repayment failure, they may have to take up another credit for repayment or even risk to lose their land. Innovative ideas and lessons are derived from the research results and can be adapted to other contexts to provide solutions for farmers and financial institutions.

Keywords: Agricutural finance, Benin, savings and credit, smallholder farmers

Contact Address: Karin Gaesing, University of Duisburg-Essen, Inst. for Development and Peace (INEF), Duisburg, Germany, e-mail: karin.gaesing@uni-due.de

Improved forage seed markets in East Africa: developments, bottlenecks, and future opportunities

Jesús Fernando Florez, Peggy Karimi, John Jairo Junca Paredes, Natalia Triana-Angel, Stefan Burkart

The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia

In East Africa, forages are the main feed source for dairy cattle. Producers use local varieties but in recent years there has been a sustained increase in the adoption of improved forage varieties and hybrids aimed at increasing productivity and improving adaptation to climate change. However, little is known yet about the forage seed market and how it can be improved to further boost the adoption of improved materials. The objective of this research is to describe the behaviour of the seed market for improved forage varieties and hybrids in East Africa in recent years and to develop a perspective analysis on how this market is expected to evolve over the next decade, in addition to identifying the main bottlenecks and opportunities for improvement. We applied a qualitative approach based on semi-structured interviews with stakeholders from the forage value chain in 10 East African countries. Our research covered three pillars, namely i) the past: how did the forage market evolve over the last ten years, ii) the future: how could the market evolve over the next ten years, and iii) bottlenecks and opportunities for improvement. A total of 46 key informant interviews were carried out. We found a virtuous circle that could facilitate the acceleration of the adoption of (hybrid) forages in East Africa. Research centres want to continue their breeding and seed selection programmes to improve existing varieties and bring new varieties on the market. Seed companies are interested in increasing their supply of seeds both in terms of quantities and diversification of varieties. Governments and development organisations express their interest in continuing to support and finance the promotion and adoption of (hybrid) forages. Producer associations plan alliances with seed companies to distribute seeds among their producers at more affordable prices. Finally, dairy farmers are interested in (hybrid) forages to increase milk production, maximise the space used for cattle farming, and reduce their vulnerability to climate change.

Keywords: Forage hybrids, improved forages, Megathyrsus maximus, seed systems, Urochloa

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The processes behind the consolidation of sustainability policies in Colombia: Evidence from the policy for sustainable cattle 2022–2050

Manuel Díaz[1], Leonardo Moreno Lerma[2], Stefan Burkart[1]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*
[2]*Independent Consultant, Colombia*

Global projections for the agricultural sector indicate that environmental indicators like deforestation, loss of biodiversity, and greenhouse gas emissions will continue to rise for the period of 2018–2030, with livestock accounting for more than 80 % of this increase. This has prompted the response of various governments, which have committed to taking mitigation measures. The Policy for Sustainable Cattle 2022–2050 in Colombia is one of the most ambitious efforts to support the pledges by encouraging the switch from conventional cattle farming to sustainable production systems and value chains. To serve as a catalyst for events that will allow policy makers to promote sustainability in similar contexts, this study attempts to use the Kaleidoscope Model of Policy Change to identify the exogenous and endogenous political system factors that facilitated the path towards the consolidation of the policy. Two qualitative methods were used to apply the framework: semi-structured key informant interviews and an extensive literature review to broaden the context provided by the experts. The main emphasis was placed on the first three stages of the model, namely a) Agenda Setting, b) Design, and c) Adoption. The results reveal that sustainability policies emerge in the political system not as isolated initiatives promoted by independent agents but through a series of events and synergistic agents that coordinate activities towards that purpose. Policies are a consequence of a set of factors where no single factor explains the change. Instead, change is the result of the accumulation and interaction of internal and external demands, political will, local policies, laws, and knowledge. In addition, although no clear veto players were identified, sustainability policies are at risk when the design is funded by international aid and the internal actors in charge of funding during the implementation phase are not specified. Conclusions highlight the importance of an observatory to analyse environmental, social, and economic indicators, as well as the implementation of new tax instruments (e.g., carbon taxes) to avoid strong dependence on international institutions.

Keywords: Kaleidoscope model of policy change, Latin America, livestock

Contact Address: Stefan Burkart, International Center for Tropical Agriculture (CIAT), Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Policy performance and stakeholders' perspectives on achieving sustainable food production in Namibia

Gideon Mawenge, Christine Wieck

University of Hohenheim, Dept. Agricultural and Food Policy (420a), Germany

In contribution to achieving international sustainable development goals, Namibia adopted the 2030 sustainable development global agenda in the year 2018 and guaranteed comprehensive implementation of the agenda in a national spirit of leaving no one behind. The 2030 global agenda for sustainable development addresses climate change, poverty, and inequality pointing to the call for a Sustainable Food System (SFS). SFS encompasses a set of structures and interconnected activities with significant contributions to the food value chain as a pillar for sustainable development. SFS structures originate with Sustainable Food Production (SFP) activities employed by key players, such as food producers. It is therefore imperative to comprehend the national SFP strategies of a country and its systems, processes, institutions, and agricultural legislation that guides and supports multi-stakeholder governance to achieve SFP targets. Hence the objective of this research paper is to identify Namibia's main policies that support the implementation of SFP targets. In so doing, the paper will analyse and reveal policy performance to achieve SFP based on national reports and stakeholders' perspectives.

Revolving around the sustainability compass at pivotal phases of the policy process, this research paper implements the policy evaluation process phase as a significant feedback control system in agenda-setting for sustainability. A qualitative policy analysis approach known as frame-critical analysis was used in this study. Analyses are from Namibia's national policies, agricultural legislation, national reports, and stakeholders' perspectives collected through in-depth interviews composed of academia, state-owned, private sector, and civil society organisations. A semi-structured interview strategy guided by open-ended questions was used supplemented by follow-up and probing questions depending on the interviewee's response.

This study shares the main policies supporting the implementation of SFP, discusses primary stakeholders and national documents' response to policy performance, and reveals Namibia's approach to achieving SFP targets. The findings will provide policy performance feedback and encourage policymakers and economic development professionals to understand the national approach and required action to enhance SFP in Namibia.

Keywords: Frame-critical analysis, Namibia, national documents, policy, stakeholders' perspectives, sustainable food production, sustainable food systems

Contact Address: Gideon Mawenge, University of Hohenheim, Dept. Agricultural and Food Policy (420a), Halfgarten 13, 70593 Stuttgart, Germany, e-mail: gideon.mawenge@uni-hohenheim.de

How to design sustainable urban food policies for a secure and nutritious future in Chiang Mai, Thailand: A case study of combining approaches

Piyanit Churak[1], Fred Krüger[1], Axel Drescher[1], Klaus Geiselhart[1], Kitti Sranacharoenpong[2]

[1]*University of Erlangen-Nuremberg, Institute of Geography, Germany*
[2]*Mahidol University, Institute of Nutrition, Thailand*

Urbanisation is a global phenomenon that brings about multifaceted changes. These changes include not only population migration, economic growth, and infrastructure development but also public health implications. Transformation from rural-like to urban-like activities in food systems and food policies has made these systems more complex than in the past. Chiang Mai's food system is facing several challenges, including a loss of agricultural land due to urbanisation, food insecurity in rural areas, unsustainable agricultural practices, limited market access for small-scale farmers, insufficient food waste management, and climate change impacts. Addressing these issues will require collaborative efforts from the local government, civil society, and private sector. The objectives of the study are to understand food systems related to food consumption practices in urban and peri-urban communities in Chiang Mai, Thailand, and to check on and, where deemed necessary, co-design community goals and practices of sustainable food consumption for policy planning.

The study focuses on four concepts: 1) studying of food systems through methods such as documentation, observation, open-ended interviews, Fundamental Geographic Data Sets (FGDs), community mapping, and mental mapping to depict food systems and to identify stakeholders, 2) assessing dietary intake of people in target areas, 3) assessing key drivers and uncertainty in food system changes and exploring directions to improve food systems, and 4) emphasising on a value chain of a selective local food product. Expected outputs will be a set of foundational information on food systems, drivers and unpredictability in food system transformations, and possible ways to improve food systems. Visions acquired from diverse actors related to food systems will give possibilities for desired future food systems. A food value chain analysis will also strengthen this study and contribute to a more holistic approach.

To conclude, the active participation of communities is crucial for advancing policies and programmes that foster sustainable and resilient cities. This study underscores the significance of involving relevant stakeholders to gather different perspectives on shaping the future of food systems. Ultimately, this approach is expected to yield tangible benefits for these communities as part of the project's positive outcomes.

Keywords: Community, food security, food systems, sustainability, Thailand, urban

Contact Address: Piyanit Churak, University of Erlangen-Nuremberg, Institute of Geography, Wetterkreuz 15, 91058 Erlangen, Germany, e-mail: piyanit.churak@fau.de

Assessing the decision-making process to evaluate the institutional governance related to the implementation of forest landscape restoration in Irodo watershed, Madagascar

HAMY RAHARINAIVO[1], ZO HASINA RABEMANANJARA[2], KATHARINA LÖHR[3], NAOMI WEISS[4]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*
[2]*University of Antananarivo, Higher School of Agronomic Sciences, Madagascar*
[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*
[4]*Humboldt-Universität zu Berlin, Germany*

Madagascar has pledged to restore 4 million hectares of forest as part of the Bonn Challenge to combat environmental degradation and climate change. To achieve this challenging goal, governance has been identified as a priority by several researchers engaged in restoration. However, no regional study has yet been carried out in the pilot region of Diana, where the Ministry of Environment is implementing initial activities with the support of GIZ, even though the deadline is less than a decade away.

This study offers an approach to analyze, the main stakeholders engaged in FLR implementation. We identify the main actors, analyze the interlinkages between them and explore the policy and wider decision-making processes that contribute to shaping FLR activities today.

The results offered by the Governance Analytical Framework of Hufty showed that the main actors, both public and private, who participate directly in FLR activities are primarily those working in the environmental sector. Thus, other major stakeholder groups working in other sectors need approaches that are more in the nature of simple invitations to FLR-related events in order to raise their awareness and interest in involvement in FLR implementation activities. The strategic mobilization of FLR actors promotes the implementation of activities and contributes to the sustainability of interventions and effective results.

Although the analysis of legal texts reveals inconsistencies between the environment, agriculture, and land use sectors, the analysis of local decentralized levels shows that they are motivated to promote FLR and gives hope for a greater commitment to FLR in the future.

Keywords: Governance, implementation, land use, stakeholders, strategy

Contact Address: Hamy Raharinaivo, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder Straße 86 , Müncheberg, Germany, e-mail: hamymolie@gmail.com

Soil governance a constrain to soil security in Africa: A case study in Ghana

Justice Ankomah-Baffoe[1], Prince Martin Gyekye[1], Benjamin Ason[2], Muhammed Charmawla Abubakar[3]

[1]*CSIR-Soil Research Institute, Accra-Centre, Soil Survey, Mapping and GIS, Ghana*
[2]*CSIR-Soil Research Institute, Accra-Centre, Analytical Chemistry, Ghana*
[3]*IHE Delft Inst. for Water Education, Water Resources and Governance, The Netherlands*

Soil governance refers to the policies, legislations and actors (institutions) that consolidate enforce and safeguard the use and management of soil resources for sustainable production and ecosystem services. A secured and sustainable food production system in Africa demands securing the soil; a basic underpinning resource of food and water security, climate, socioeconomic and human health. Despite soil's essentiality, the soils of Africa are threatened by soil governance. These threats have downscaled nearly half of the productive potential of African soils and consequently led to food insufficiency and socio-economic instability. With the prevalence of climate variability, food shortages, pandemics and conflict, it has become crucial to address the constraints and put the governing ways of soil security in the governing systems of Ghana. This paper examined the role of the Lands Commission and Environmental Protection Agency of Ghana which are legislatively vested to undertake land (soil) entitlement registration and protection respectively. The governing mechanisms of laws, regulations, policies, and policy reforms are however inclined towards entitlement and other environmental services with very little focus on soils. The only existing law governing soil was established in 1953 (No. 32) and amended in 1957 (No 35). The law ensures effective and efficient utilisation and sustainable management of soil and provides the power to enforce regulations and policies to safeguard soils. The barriers and constraints to the governing soil laws were that the application of the law was established under the Ministry of Agriculture with no legislated protective mandate and the power of regulations was vested in the president. The law has not seen any reform or amendment since the last amendment in 1957 and has not been effectively applied and enforced. The laxity in legislation, policy and actors of soil governance in Ghana leads off to soil security threats.

Keywords: Ghana, governance, policy, security, soil

Contact Address: Justice Ankomah-Baffoe, CSIR-Soil Research Institute, Accra-Centre, Soil Survey, Mapping and GIS, P.O.Box m23, Accra, Ghana, e-mail: ankoba.just@gmail.com

Effect of contract farming on farm productivity among sorghum farmers in Dodoma, Tanzania: Endogenous switching regression

THEDY KIMBI[1], FULGENCE MISHILI[1], CHRISTOPHER MAGOMBA[1], STEFAN SIEBER[2], ESSEGBEMON AKPO[3]

[1]*SUA, Department of Agricultural Economics and Agribusiness, Tanzania*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*
[3]*ICARDA, Lebanon*

Despite the importance of sorghum production and its increased market demand in the sub-Saharan region of Africa in recent years, a significant number of smallholder farmers still face issues of low and poor yields, lack of reliable markets, low grain prices and low-income levels. Following the strategic focus of the national development five year (2018–2024) strategic plan by the Government of Tanzania that is in line with the Africa Agenda 2063 on transforming Africa's agriculture into modern one, strategies as contract farming are designed and implemented in the country to solve agricultural problems among smallholder farmers. It is thus important to evaluate the impact of such strategies especially in developing countries. This study analyses the effect of CF in sorghum production using the cross-sectional data collected from 400 smallholder sorghum farmers in Tanzania. The estimation model that was used for analysis was the endogenous switching regression, and findings show a positive and significant relationship between CF and farm productivity. Moreover, findings identified location, age, household size, hired labour, a family-hired labour mix, own land use, own and rented land use under production, access to extension services, access to financial services and number of groups per village as determinants of CF participation among sorghum farmers. Therefore, it is evident that CF is among vital strategy in sorghum production as it has enhanced higher farm productivity levels among contract farmers compared to noncontract farmers. Furthermore, it is important that policies to emphasise CF and stakeholder partnerships along the sorghum value chain to be prioritised.

Keywords: Contract farming, endogenous switching regression, farm yield, sorghum, Tanzania

Contact Address: Thedy Kimbi, SUA, Department of Agricultural Economics and Agribusiness, Morogoro, Tanzania, e-mail: kimbithedy@gmail.com

ID 457

Catalyzing private finance into climate-smart agriculture: The science-driven accelerator program

Hauke Dahl

International Water Management Inst. (IWMI), Southern Africa Office, South Africa

The agriculture sector is the economic backbone for most developing countries and is crucial for strengthening food security, increasing incomes and driving inclusive and sustainable growth. However, the sector remains untapped due to low levels of productivity exacerbated by the effects of climate change. To strengthen resilience to climate change and efficient functioning of food systems, significant financial investment is required. The public sector and donors cannot handle this alone; the private finance and investment sector needs to increase its financial commitments. Yet high perceptions of sector and country risks and the inability to assess and manage these risks, lack of available market data and high transaction costs hinder the private sector's investment in agriculture. Additionally, for-profit businesses operating in a climate-smart way across agricultural value chains often lack the commercial and technical capacity to scale agricultural research innovations. Bringing innovations to scale requires a holistic approach. Innovation and impact management literature indicated that scaling innovations via a development project focusing only on a single innovation have limited success in scaling. It has been shown that it is necessary to integrate innovation processes with capacity development, finance and other complementary solutions. One novel way to achieve this integration is through an accelerator program. Accelerator programmes are considered promising approaches to support growth-driven, for-profit companies in their goal to reach scale as they provide an institutional space for integrating innovations with complementary solutions. However, there is little systematic and empirical evidence of the performance of accelerator programmes for scaling science-based innovations in low- and middle-income contexts. Market analysis shows that many companies that have the potential to bring innovations to scale already exist. However, macro-scale challenges and shocks (droughts, recession, covid-19 pandemic) in a fragile market environment discourage entrepreneurial appetite, hindering thinking beyond short-termist revenue targets. A science-driven accelerator programme for climate-smart agribusinesses opens up opportunities to create a pipeline of de-risked, and science-based investment solutions into sustainable agriculture in the Global South.

Keywords: Business acceleration, innovation scaling, sustainable finance

Contact Address: Hauke Dahl, International Water Management Institute (IWMI), Southern Africa Office, Block G Ground Floor, Hatfield Gardens, 333 Grosvenor St, Hatfield, 0083 Pretoria, South Africa, e-mail: H.Dahl@cgiar.org

A policy mix for achieving ambitious goals on forest landscape restoration: analysing coherence and consistency in Ethiopia forest-related policy

Musse Tesfaye Gebre, Jude Ndzifon Kimengsi, Lukas Giessen

Technical University of Dresden, Inst. of International Forestry and Forest Products, Germany

As a result of the rising global trends of land degradation and deforestation, the concept of forest landscape restoration (FLR) has gained worldwide recognition as an approach that complements cross-sectoral integration and aims to restore multiple forest ecosystem services across a wider landscape. Nonetheless, it remains unclear how to integrate this approach with previous and existing policy domains, which creates challenges for policy design that could lead to conflicting goals and inconsistent use of policy instruments. The objective of this study is to present new methodologies for analysing the FLR policy mix, given the growing complexity of the policy design problem in Ethiopia. A cross-impact matrix (CIM) methodology is applied to assess the coherence of goals and consistency of instruments in the FLR. Thus, eleven major goals, and forty-six policy instruments (regulatory, economic, procedural, and information) were identified in the forestry, agriculture, climate, and mining sectors. The result demonstrates varying levels of consistency and coherence between goals and instruments in the FLR policy mix. Thus, consistent economic instruments like reducing emissions from deforestation and forest degradation (REDD+) create a positive and conducive environment to implement other instruments. Whereas inconsistent regulatory instruments like the acquisition and use of rural land have shown negative rippled effects throughout the system. We conclude that a comprehensive methodological approach is crucial to get an optimal outcome from the FLR policy mix. We argue that our methodological approach could be used elsewhere for similar studies to better design and manage policy instrument mix and coherence of FLR-related policy goals.

Keywords: Consistency, cross-impact matrix, cross-sectoral integration, forest landscape restoration, policy instruments, policy mix

Contact Address: Musse Tesfaye Gebre, Technical University of Dresden, Inst. of International Forestry and Forest Products, Blochmann straße 15, 01069 Dresden, Germany, e-mail: mussetesfaye36@gmail.com

The interdependence of different measurements of natural resources dependence and poverty: Comparative evidence from Vietnam

Eva Seewald, Ulrike Grote

Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Germany

Poverty and climate change are two major problems developing countries face with severe impacts on wellbeing. While environmental resources support poor households by providing firewood and other non-timber forest products (NTFP), natural resource extraction worsens degradation. The literature shows that NTFP can support poor households' tight budgets and dependence on NTFP is higher for the poorest households. This can be seen as a coping mechanism in times of shocks. Dependence of households on NTFP has been measured mostly by relative income from NTFPs which may not capture dependence correctly if NTFPs are mainly used for home consumption. Additionally, poverty is defined by a scarcity of money but it also captures other aspects of life such as no access to health services. To capture this, researchers developed multi-dimensional poverty indices (MPIs).

Natural resource stocks have been reduced due to economic growth in Vietnam making research especially important. Additionally, the impact of households' dependence on environmental resources on multidimensional poverty has not been studied. As MPIs incorporate aspects such as health and education the results may differ from poverty solely measured by income leading to different policy implications and giving a more deeply insights on the determinants of poverty and dependence on NTFPs.

Therefore, we use a large socio-economic panel data set from Vietnam from 2013 until 2017 to calculate an index measuring dependence on environmental resources (EDI) and a MPI. The aim of this article is, thus, to give a step-by-step analysis to show the different results using different measures for natural resource dependence and poverty of poor rural households in Vietnam.

The results show that dependence on natural resources increases poverty independent on the measurement of poverty and environmental resource dependence. The effect is largest if we use monetary poverty and relative income from natural resources. However, the results are most significant when using MPI and the EDI. This implies that it is important to account for the measurement of poverty and the dependence on natural resources when policy makers try to address poverty as well as environmental issues by restricting the access to forests or non-forests sites for collecting.

Keywords: Climate change, climate change adaptation, multi-dimensional poverty, natural resource dependence, natural resource extraction, poverty

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Contact Address: Eva Seewald, Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: seewald@iuw.uni-hannover.de

Is there a future for small farmers in bioeconomy? The case of improved seeds in South Punjab, Pakistan

Mehwish Zuberi

Eberswalde University for Sustainable Development, Faculty of Forest and Environment, Germany

Small farmers are key players in agrarian value chains, particularly in the Global South, but they are often neglected in the planning of technology-oriented agricultural interventions featured prominently in bioeconomy policies. As global demand for food and biomass is expected to rise, production increase through (bio)technological means is framed as a necessity, but has been debated for its ecological and social sustainability. We add to this debate by investigating the possibilities and challenges for smallholder farmers to participate in the intensification of production in an emerging bioeconomy. We scrutinize the case of Pakistan, an agricultural country where 65 percent of farms operate less than 2 ha of land and where bioeconomy approaches such as biotechnology and advanced plant breeding have gained momentum in policy debates. We specifically analyse a cornerstone of the bioeconomy value chain—namely 'improved' seed varieties—by looking at the experiences of small farmers with genetically modified cotton and hybrid maize. This contribution builds on qualitative data from South Punjab between 2019 and 2022. Small farmers value improved seeds and prefer shorter duration crops for faster profit cycles. Informal exchanges through seed saving and sharing enable widespread access of market seeds. However, the poorest strata are hindered from adopting improved seed varieties due to lack of resources, established crop rotation patterns, and frequent oscillations of the cropping trends. Market and climatic factors also limit the profitability of improved seed varieties as higher input costs disproportionately affect small farmers. Furthermore, highly productive crops and frequent crop cycles result in surging tenancy rates for small land holders and can lead to their expulsion from agriculture. Our results contribute to the understanding of the complex role of small farmers in the Global South under a bioeconomy scenario.

Keywords: Bioeconomy, global south, improved seeds, small farmers

Contact Address: Mehwish Zuberi, Eberswalde University for Sustainable Development, Faculty of Forest and Environment, Schicklerstr. 5 (intern Haus 22.1), 16225 Eberswalde, Germany, e-mail: mehwish.zuberi@hnee.de

Barriers to the progress of the organic agriculture system in Iran: A thematic hierarchical mapping

Arezou Babajani[1], Sahar Ahmadi[1], Sabine Zikeli[2]

[1]*University of Hohenheim, Agricultural and Food Policy Department, Germany*
[2]*University of Hohenheim, Center for Organic Farming, Germany*

Despite the fact that organic agriculture in Iran has many potentials in both production and consumption sides to improve the sustainability in food sector, the trend of progress of this sector in terms of the area and share of total agricultural land has been negative and up to the point that the most recent report from FiBL & IFOAM (Willer et al, 2023) indicates that it is now zero. Currently (in 2021), 7053 ha of the entire country are under organic farming practices, compared to 11916 ha or 0.03 percent of all agricultural areas during the previous year (2020). The low development of organic products in Iran is due to a number of factors and barriers, including lack of willingness of agricultural policy makers due to food security concerns, low consumers' awareness and purchasing power, insufficient financial, educational, and informational support for organic farmers from the government, conflicts between responsible organisations, lack of certification system and producers' lack of knowledge of the product's characteristics and production processes as a result of lack of market demand and extension education. Because of sanctions and political issues, some of these challenges are unsolvable, but others can be overcome with the help of supportive strategies and policies. By performing a systematic literature review and thematic analysis of articles that have been published over the past two decades (from 2000 to 2023) in both English and Persian and in the major Iranian and international scientific databases and drawing a thematic hierarchical map in MAXQDA, the current study has examined the barriers and challenges of organic agriculture in Iran and identified the reasons for its failure. The study's findings indicate that there are three primary categories of obstacles in this regard: political, demand, and supply sides. The policy side encounters the most challenges, with 18 major barriers, followed by the supply and demand sides, with 17 and 11 barriers, respectively. It reveals how political changes in organic farming play a crucial role in making it easier for Iran's agricultural and food system to convert to organic farming.

Keywords: Organic agriculture obstacles, organic farming in Iran, thematic analysis

Contact Address: Arezou Babajani, University of Hohenheim, Agricultural and Food Policy Department, Schwerzstraße 46 , 70593 Stuttgart, Germany, e-mail: arezou.babajani@uni-hohenheim.de

Institutional development and land-use dynamics at the agricultural frontier in the Peruvian Amazon

Miguel Angel La Rosa Salazar

Humboldt-Universität zu Berlin, Agricultural and Food Policy Group, Germany

The doctoral research aims to comprehensively understand the institutional landscape shaping the agricultural frontier in the Peruvian Amazon (AFPA). The Amazon region is subjected to an extractivist policy framework that oversimplifies its complexity, and a more holistic policy-making approach is required. Therefore, untangling the diverse institutions involved in shaping land-use dynamics is crucial. To look at the AFPA is an essential part of such an effort.

The research seeks to answer the following question: How do multiple institutions shape land-use dynamics in the AFPA? The study goes beyond identifying correlations and variables and aims to depict stories that explain how the AFPA develops, considering differences across various areas.

The research focuses on the institutionalisation of discourses and their connection to the AFPA's institutional landscapes, including the various institutions that influence the dynamics of agricultural frontiers in Amazon lands in Peru. The study covers diverse scales of agriculture and does not limit its reach to the agriculture sector only. It also presents different levels of analysis, from local to international trade (legal or illegal) and policies. Furthermore, the AFPA is approached as a social-ecological system, allowing for the consideration of its complexity.

The study comprises three parts. The first part is a systematic literature review of the role of institutions in agricultural frontiers, focusing on research traditions and methods applied to this topic. The second and third parts address the different levels of influence on the AFPA. Part two considers national and international levels, covering markets and political endeavours. As the Peruvian Amazon is not homogeneous, the third part will consist of three case studies. Both parts include documentary reviews and semi-structured interviews, with diverse literature and statistics providing additional context.

The research will support efforts to conserve the Amazon region and promote sustainable food provision. It will hopefully inspire conservation measures for other social-ecological systems. Also, this study intends to display the necessity of coordinated efforts to understand and deal with the various ecological problems in Peru and other regions.

Keywords: Agricultural frontier, Amazon, discourses, institutions, social-ecological systems

Contact Address: Miguel Angel La Rosa Salazar, Humboldt-Universität zu Berlin, Agricultural and Food Policy Group, Philippstraße 13 - haus 12 A, 10115 Berlin, Germany, e-mail: lamiguel@hu-berlin.de

ID 376

Social justice and gender

Gender and intersectional perspectives in transforming food systems

Online posters

Gendered livelihood strategies and food security of cacao smallholders in Alto Sinú, Colombia

Lina Tami-Barrera

The Pennsylvania State University, Department of Agricultural Economics, Sociology, and Education, United States

After four decades of anti-drug policy implementation in Colombia, in 2021, the 'illicit crops' area reached a new record, 204,000 hectares. This fact triggered a wave of questioning about the effectiveness of alternative development (AD) programmes in materializing alternative livelihoods for smallholders and collectors involved in coca cultivation. Likewise, criticisms pointed out the lack of gender-sensitive approaches, putting additional constraints on women's access to assets, decision-making, and livelihood outcomes control.

In AD programs, several crops (e.g., coffee, oil palm, cacao, rubber) have been promoted as promising sources for replacing coca income. However, most of them still seem ineffective in alleviating poverty and making households capable of coping with economic and environmental stresses. The last UNODC report indicated 86 % of coca areas have remained in the same regions for more than ten years, partly in response to the vulnerable socioeconomic conditions of communities that see coca as a means of subsistence. The net income of smallholders can reach 78 % of coca production value, while through other agricultural activities, obtain 53 %. Particularly, government and international aid have spent significant resources fostering cacao agroforestry systems (CAFS) among smallholders willing to abandon coca. Between 2003 and 2017, AD programmes established 79,500 hectares, corresponding to 45 % of the total cacao area by the end of this period. Although CAFS are multifunctional systems capable of providing numerous benefits to households (e.g., income, food security, nutrition diversity, resilience capacity, restoration of degraded ecosystems), there is little understanding of how CAFS, combined or not with other activities, shapes household livelihoods and goals. Besides, little attention is paid to how gender relationships influence asset access, decision-making, and livelihood strategies of households in AD contexts. Drawing from two cases of rural communities served with AD cacao projects in northern Colombia, this presentation seeks to show preliminary results by examining the following questions: i) What are the livelihood strategies pursued by households served with AD cacao projects in Alto Sinú? ii) How do gender relations and livelihood strategies intersect in cacao households in Alto Sinú?, and iii) What livelihood strategies and gender relations respond most effectively to food insecurity?

Keywords: Cocoa agroforestry systems, food security, gender, livelihoods strategies

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Contact Address: Lina Tami-Barrera, The Pennsylvania State University, Department of Agricultural Economics, Sociology, and Education, 311 armsby building, 16802 University park, United States, e-mail: lmt50@psu.edu

ID 414

How do gender-caste intersectionalities influence the involvement of communities in organic cotton farming?

Kushala Witharanage[1], Akanksha Singh[2], Christine Bosch[1], Regina Birner[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland*

The socioeconomic and environmental benefits of organic farming have been widely explored in research, while topics like gender equity and labour are often neglected. In India, the influence of caste and gender identities adds another layer of complexity to these aspects. Using a case of a research and training project implemented in the Nimar Valley region of Madhya Pradesh since 2007, we explore gender and caste intersectionalities within conventional and organic cotton farming systems. The project promotes organic cotton cultivation and food crop diversification, and trains women from marginalised tribal communities, among others. We use a relational approach, as proposed by David Mosse, to understand differences in organic and conventional cotton farming systems in the representation of caste and gender and concerns and barriers to the involvement experienced by different actors. We interviewed 80 respondents employing participatory social network mapping, gendered seasonal calendars, in-depth interviews and participant observation in training, applied during a three-month fieldwork in 2022/23. Preliminary results show among others that, representation in terms of caste and gender has been static in both conventional and organic farming systems. Mainly females from scheduled castes (SC, Dalits) and scheduled tribes (ST, Tribals) are represented as casual labourers in seeding, weeding and cotton picking. The bargaining power of labourers, deciding both wages and working hours, has increased in recent years. This potentially is a positive social change, but puts a higher burden on organic cotton farmers as it is more labour-intensive compared to conventional farming. Our results further indicate that due to high labour wages, there is a resurgence of labour-sharing arrangements for cotton harvesting amongst rich upper-caste farmers and, novel involvement of upper-caste women in cotton farming activities. Tribal farmers in turn start growing conventional cotton. Also, with less cultivable land owned, project activities are less accessible to Dalits. We emphasise that ensuring direct benefits for Dalits in project activities would contribute to increasing equity and promoting pro-poor outcomes, albeit potentially increasing the costs of organic cotton. These could be offset by higher prices for organic cotton. Further more women-inclusive training could potentially lead to synergies, e.g. with cotton quality.

Keywords: Caste gender intersectionality, India, organic cotton farming, production relations

Contact Address: Kushala Witharanage, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), D-70599 Stuttgart, Germany, e-mail: kushala.elgiriyawitharanage@uni-hohenheim.de

Asset control among rural households in Petén, Guatemala: Evidence on gendered and joint decision making

Dietmar Stoian[1], Aruna Kainyande[2], Aldo Rodas[3], Iliana Monterroso[4], Lukas Giessen[2]

[1]CIFOR-ICRAF, Sustainable and Equitable Value Chains, Germany
[2]TU Dresden, Inst. of International Forestry and Forest Products, Germany
[3]Ministry of Agriculture and Livestock, Natural Resources and Agrotourism, Guatemala
[4]Center for International Forestry Research (CIFOR), Equal Opportunities, Gender, Justice and Tenure, Guatemala

The complexity of household decision making over livelihood assets poses a significant challenge and has development implications. A growing body of literature sheds light on gendered decision making in farming households, with the aim to identify patterns of inequality and underlying factors. In our analysis of six community forest enterprises (CFEs) in the Maya Biosphere Reserve in Petén, Guatemala, we adopted a gender lens for a survey among CFE member households by defining 17 areas of decision making linked with natural, human, social, physical and financial capitals. Based on a random sample of 170 households, we sought to identify areas of gender-differentiated decision making and those where decisions are taken jointly. Women and men respondents were asked separately about each other's role in decision making for cross-checking.

Results varied across households and livelihood assets, both in terms of perceived roles in decision making and decision making as such. Male involvement was particularly strong in decisions related to natural, physical, and social capitals. Women's involvement was relatively stronger for human capital, particularly regarding decisions on health and child education. Perceptions on each other's role in decision making were congruent between women and men for some areas, but markedly different for others. Such discrepancies can be linked with gender norms attributing decision-making authority in certain areas to men or women. Importantly, despite patterns of gender-differentiated decision making across the four capitals mentioned, we found a significantly higher level of joint decision making with regard to financial capital. This is striking as decisions around household income have widely been purported to be male dominated.

The results suggest that, despite decisions over certain livelihood assets being skewed towards one gender, financial capital stands out as an area of joint decision making. Being an integral part of a household's economic base,

gender-equitable control over financial capital underscores a prominent role of women in household decision making in the CFEs surveyed. The methodological approach pursued and the results have implications for policies and development interventions aimed at transforming gender relations in rural households in pursuit of gender equality.

Keywords: Decision making, gender equality, livelihood assets, Maya Biosphere Reserve

Developing women's empowerment in energy index: Conceptual framework and empirical evidence

VIDYA VEMIREDDY[1], MUZNA ALVI[2], PRAPTI BAROOAH[2], CLAUDIA RINGLER[3]

[1]*Indian Institute of Management, Ahmedabad, Centre for Management in Agric., India*
[2]*International Food Policy Research Institute (IFPRI), India*
[3]*International Food Policy Research Institute (IFPRI), United States*

Equal access to clean energy is key to meeting SDGs 5 (Achieve gender equality and empower all women and girls) and 7 (Ensuring access to affordable, reliable, sustainable, and modern energy services for all). However, energy access is not distributed equally around the world, with more than 80 % of energy poverty, that is the lack of access to sustainable, modern energy services and products, concentrated in rural areas, where it affects agriculture, food security and nutrition, and reduces livelihood opportunities and well-being. At the same time, a transformation in energy technology and resources is underway as the world moves to more efficient ways of conducting day-to-day activities while enhancing productivity. But are the gains from energy transformation distributed equitable within and across countries, communities and households? Research has established that compared to men, women spend a disproportionately large portion of their time in non-income generating activities in the household, and increasingly also in productive work such as agriculture and off-farm work. However, when it comes to equity in access to efficient energy resources, gender gaps remain vast. Research examining gender differentiated patterns of energy use or access, and the role that women's empowerment plays in this, is scant. Our paper develops a framework to inform the relationship between empowerment and access to energy in rural areas. We supplement this with detailed survey data from India, Pakistan, and Nepal, empirically examining the linkage between energy access, women's empowerment and household well-being. We hypothesise that multiple dimensions of empowerment such as mobility, agency, and control over income, are the main drivers as well as outcomes of equitable energy use and access. We contribute to the knowledge gap by first, reviewing the extant literature to understand the gender-differentiated patterns of access or use of energy and the role of women's empowerment. Second, we develop a theoretically grounded conceptual framework to study energy and women's empowerment and identify a set of indicators that can be used to measure women's role in a rural and developing country context. Finally, we present empirical evidence linking women's energy use portfolio to measures of empowerment in South Asia.

Keywords: Empowerment, energy, gender, irrigation, South Asia

Contact Address: Muzna Alvi, International Food Policy Research Institute (IFPRI), New Delhi, India, e-mail: m.alvi@cgiar.org

Gender and climate change adaptation in refugee hosting landscapes in the arid tropics of Eastern Africa

Ruth Mendum[1], Andrew Adam-Bradford[2], Solomie Gebrezgabher[3], James Kinyua Gitau[4], Desta Woldetsadik[5], Mary Njenga[6]

[1]*Mendum Consulting, Penn State University (retired), Gender Equity through Agricultural Research and Education Initiative (GEARE), Ag Sciences Global, College of Agricultural Sciences, United States*

[2]*Oxford Brookes University, Center for Development and Emergency Practice (CENDEP), United Kingdom*

[3]*International Water Management Institute (IWMI), Ghana*

[4]*World Agroforestry (ICRAF), Kenya*

[5]*Wollo University, Dept. of Soil and Water Resources Management, Ethiopia*

[6]*CIFOR-ICRAF, Climate Change, Energy and Low-Carbon Development Theme and Refugee-Hosting Engagement Landscape Programme, Kenya*

In East Africa, the majority of refugees and even host community members are adult women and children, with both groups being settled in arid drylands. In the case of refugees, men have been killed, or are staying home to participate in unrest or to protect property in country. In host communities, adult men who are able to seek work in cities, leave to earn more, some never to return. As a result of these demographic realities, the remaining adult women have high care work burdens, caring for children. These responsibilities are not just a matter of physical resources, but also critically time poverty. Gender sensitive protection is also a critical issue. Women and children need to be able to participate without encountering gender-based violence and abuse.

Burdens for both refugees and host community members include past trauma, varying levels of literacy, cultural diversity that is poorly understood, and linguistic diversity. Refugees can stay in camps for years and thus the psychological benefit of skill building to support households most pressing needs. Host community members receive little or no individual support offered to refugees and thus can be more food insecure than the newcomers, hence the necessity of incorporating a social cohesion approach.

The reality of refugee accommodation in environmentally fragile tropical drylands means that camps are considered an ecological burden. This presentation reframes refugees and impoverished host community members, especially young women, as agents of climate change adaptation. Teaching interested refugee and host communities to cultivate small home gardens irrigated with greywater, plant fruit and shade trees in their compounds, make

briquettes from charcoal dust and soil, and build more efficient stoves from local clay, reduces the impact of dense settlements on fragile landscapes. In the process, newcomers and former livestock herders displaced by drought are transformed from a social justice and ecological challenge to active restoration participants.

Keywords: Arid tropics, climate change adaptation, cooking energy, food, gender, refugees

Sustainable business models with a gender-sensitive approach for artificial cattle insemination services in the northwest highlands of Vietnam

Aura Bravo[1], Thinh Nguyen Thi[2], Phuong Nguyen Thi Minh[2], Natalia Triana-Angel[1], Huyen Le Thi[3], Karen Marshall[4], Stefan Burkart[1]

[1]International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Colombia
[2]International Livestock Research Institute (ILRI), Vietnam
[3]National Institute of Animal Science, Vietnam
[4]International Livestock Research Institute (ILRI), Kenya

The last 40 years of Vietnam's economic history have been marked by significant transformations and a dazzling market opening that impacted society's livelihoods, food preferences, and consumer demand. In this scenario, agricultural and livestock production plays a pivotal role. The livestock sector, especially poultry and pig chains, has undergone an energetic modernisation process resulting in a predominant model oriented to large and medium-scale production, with specialised breeds and greater technological adoption. However, the cattle production model remains mostly in small-scale production. Therefore, governmental plans have prioritised interventions for further the proportion of beef produced by commercial farms and improving local breeds' productivity by promoting crossbreeding with beef-specialised breeds through the artificial insemination (AI) practice. Then, initiatives implemented have focused on developing productive capacities and strengthening knowledge transfer to smallholders and veterinary workers to promote the adoption of sustainable livestock innovations. These have included breed selection, breeding, and artificial insemination (AI) techniques in cattle. Nevertheless, persistent gaps include limited supply, reduced access, and affordability of these services. This research aims to analyse the current delivery model of AI services in the northwest highlands of Vietnam. We follow the steps for developing innovative business models proposed by Osterwalder and Pigneur (2010) using the triple-layered business model canvas framework of Joyce, Paquin, and Pigneur (2015). A qualitative, gender-sensitive approach was used, conducting key informant interviews and focus group discussions with AI service providers and other stakeholders for whom the adoption of this practice in cattle is relevant (including adopters and non-adopters, women and men, farmer groups, input suppliers, and local authorities). The expected results will be articulated to develop integrated innovative models for the delivery and scaling of innovations in breeding, feeds and forages, and animal health, as well as generating evidence for their scaling in other regions.

Keywords: Breeding, cattle, delivery innovations, qualitative approach, scaling up

Can gender-intentional information campaigns through social institutions enhance women's participation in wheat seed markets?

Michael Euler, Abdu Mohammed, Moti Jaleta

International Maize and Wheat Improvement Center (CIMMYT), Ethiopia

Although many women actively participate in household crop production, farming under female responsibility is often characterised by low adoption and turnover rates of modern varieties. Enhancing equitable access to improved seeds can increase productivity of female managed cropping systems, foster social inclusion, and improve food security in the Global South. In small-scale wheat systems, female farmers often rely on informal seed sources and seeds from own stocks to obtain planting material. One major limitation to a more frequent uptake of fresh seeds includes the limited exposure and access to information on agricultural technologies, especially as women tend to be underrepresented in community-based farmer institutions and underserved by agricultural extension system. Through a randomised controlled trial, this study quantifies the effects of the delivery of gender-intentional information campaigns on the purchase of fresh wheat seeds by female farmers in Ethiopia. Implemented between May and June 2023 with 1000–1400 farmers, the study relies on existing socio-economic institutions to channel information on available varieties in the formal seed market and their agronomic properties to farmers. In contrast to conventional approaches, information campaigns are delivered through village-level institutions that are dominated by female or male members. Villages are randomly assigned to the following treatment arms: information campaigns through male dominated farmer cooperatives and female dominated women groups (T1); information campaigns through farmer cooperatives only (T2). Comparison of the share of female farmers who purchase fresh wheat seeds between treatment arms and control villages without information campaigns (C) allows the estimation of the treatment effect of gender intentional information campaigns on share of fresh seed purchases by female farmers. We hypothesise that gender-intentional information delivery has a positive effect on the purchase of fresh seeds from formal sources among female farmers in female headed households, and female farmers in dual headed households. We further postulate, that the effect of information on seed purchase is highest where female farmers already have an active role in household decision-making in crop production. Results will support the design of gender-intentional extension services, marketing, and delivery of newly released wheat varieties through the formal seed sector in Ethiopia.

Keywords: Adoption of agricultural technologies, Ethiopia, gender, village institutions, wheat

Contact Address: Michael Euler, International Maize and Wheat Improvement Center (CIMMYT), Addis ababa, Ethiopia, e-mail: m.euler@cgiar.org

Empowering rural farm women in agricultural development: A decision analysis approach with a focus on gender

ALEXANDRA P. C. KRAUSE, EIKE LUEDELING, CORY WHITNEY

University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany

Despite being extremely important for holistic research, gender is often overlooked in agricultural and development-related studies. Rural farm women in low- and middle-income countries are the main subject of rural agriculture development interventions for women's empowerment. We study factors influencing their empowerment in agricultural development to support researchers in capturing gender in development-oriented agricultural modelling efforts. We generated a literature-derived decision model by applying Monte Carlo simulation, a random sampling method, to include the uncertainty and riskiness of the decision outcome. The underlying Decision Analysis impact pathway describes women's empowerment within their social environments through gains in the areas where they are disadvantaged, i.e., education and training, economic strength, agricultural resources, health care and nutritious food, further strengthening their ability to work and, thus, financial resources. Safety is a crucial constraint for rural women since they can face danger within families and communities. We programmed the model as a Shiny app (https://femiaculture.shinyapps.io/femiaculture/) tool to be used by research teams for estimating the gains in rural women's empowerment resulting from any research efforts. The app can also support individual women using their own inputs. Based on research on prior empowerment interventions and the system of empowerment, we show that increasing gains for women and supporting empowerment is superior to the status quo if violence against women does not increase. Further holistic, system-oriented thinking and trans- and interdisciplinary research can reduce bias and include women as decision-makers over their empowerment. Such inclusive studies of female empowerment could produce actionable future models and web apps that can potentially empower rural women in different areas.

Keywords: Agricultural development, decision analysis model, empowerment, gender, rural farm women, transdisciplinary research

Contact Address: Alexandra P. C. Krause, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Science, Auf dem Hügel 6 , 53121 Bonn, Germany, e-mail: AlexandraPCMKrause@protonmail.com

Impacts of electrification on the welfare of rural households in Ethiopia: A gendered perspective

Tiruwork Arega[1], Dawit Mekonnen[1], Claudia Ringler[2]

[1]*International Food Policy Research Institute (IFPRI), Ethiopia*
[2]*International Food Policy Research Institute (IFPRI), United States*

The aim of this paper is to examine the gendered benefit streams of household- and village-level electrification rural households in Ethiopia. Using three rounds of panel data, we provide insights into the gendered impacts of electricity infrastructure on school children, non-farm income, and women empowerment. The results of our study indicated that the benefit streams of electricity are clearly gendered, affecting women and men differently. The scale of electrification shows a correlation with years of schooling completed by boys' and girls'. School-age girls benefit from electricity infrastructure when the household they live in has access to electricity whilst village electrification has a greater spillover effect on boys' years of schooling completed. We found a positive and strong association between women-headed household off-farm income and village electrification; suggesting women's level of commitment to operating non-farm business and a robust ability to translate village-level electricity into economic opportunities. Moreover, adult women living in electrified households appear to have improved decision-making agency and more autonomous control of key business equipment. The result highlights that girls level of education and women decision-making power are enhanced by household-level electrification. Notably, neither girls' school attendance nor adult women's decision-making authority correlate positively with village-level electrification; thus, even in electrified villages, improving girls' and women's welfare requires tailored and complementary investments in both on- and off-grid options at household level. Our findings further suggest the importance of considering the gendered needs and different energy requirements of females and males during the planning and implementation of rural electricity infrastructures.

Keywords: Electrification, Ethiopia, gender, non-farm income, schooling, women's empowerment

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Farmer field schools in southeastern Madagascar: Best practices for gender-sensitivity

Sarah Tojo Mandaharisoa[1], Jonathan Steinke[2], Narilala Randrianarison[1], Denis Randriamampionona[1], Stefan Sieber[3], Harilala Andriamaniraka[1]

[1]*University of Antananarivo, Tropical Agriculture and Sustainable Development Dept., Madagascar*

[2]*The Alliance of Bioversity International and CIAT, Digital Inclusion, Italy*

[3]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

The Farmer Field School (FFS) approach is used by many development projects in low- and middle-income countries to promote agricultural technologies among smallholder farmers. Typically, this involves a fixed group of members meeting regularly to discuss farming challenges, receive practical trainings, and practice new techniques on a joint plot. Within a project targeting food and nutrition security in southeastern Madagascar, three NGOs have implemented individual variations of the FFS approach in three different districts, each targeting women in reproductive age (15 – 49 years). Because women's involvement in agriculture is often marginalised in southeastern Madagascar, this study aims to identify best practices for including women in FFS. To describe the three FFS approaches and their respective benefits and disbenefits from the women farmers' perspective, we interviewed 60 women FFS members, three NGO representatives, and three local agronomists in charge of supervising the FFS groups. We also observed 11 FFS sessions and held 20 focus group discussions with women FFS members. Interviews and focus group discussions were transcribed verbatim and analysed through thematic coding. We found that participation in FFS is often challenged by women's high workload of household chores and the perceived difficulty of the techniques. Adoption of the promoted practices can be limited, for example, by their physical difficulty (e.g., digging holes), women's low decision-making power in their family's agriculture, single women's lack of access to manure, and mental barriers that consider specific activities as 'men's duties'. However, we also identified multiple best practices for increasing the gender-inclusiveness of FFS. This includes timing FFS sessions with women's daily chores by holding sessions early in the morning for example, avoiding long walks by setting up vegetable gardens near houses, combining agriculture-focused FFS activities with social and non-farming activities, such as cooking demonstrations, focusing on agricultural practices that require little physical effort. Our findings provide recommendations for increasing the gender-sensitivity of FFS in southeastern Madagascar. These best practices can help development stakeholders to enhance the involvement of women farmers in agricultural training activities, to improve their productivity and to strengthen their livelihoods.

Keywords: Agriculture, gender, Madagascar, qualitative research

Contact Address: Sarah Tojo Mandaharisoa, University of Antananarivo, Tropical Agriculture and Sustainable Development Dept., Antananarivo, Madagascar, e-mail: tojmands@yahoo.fr

Are animal breeding technologies shifting gender norms? The case of Tanzanian small-scale dairy farming

Immaculata Okeke[1], Juliet Kariuki[1], Alessandra Galiè[2], Julie Ojango[2], Eliamoni Lyatuu[2], Mizeck Chagunda[1]

[1]*University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany*
[2]*International Livestock Research Institute (ILRI), Kenya*

Gender dynamics and norms are crucial for rural livelihoods and achieving food security. While norms related to ownership, management, product distribution, and sales methods are prevalent in dairy production, little research has been conducted in this area. This study hypothesised that innovations introduced without considering gender dynamics and norms may limit the extent of transformative change. Using gender-sensitive mixed methods, this study investigated the implications of introducing technologies for intra-household dynamics and gender norms in dairy-producing communities. The African Asian Dairy Genetic Gains Programme (AADGG) has been introducing improved dairy breeding technologies in smallholder dairy farms in Tanzania. This served as the study case. Intra-household data were collected from 180 smallholder farmers surveys, gender-aggregated focus group discussions involving 80 farmers, and six expert interviews. Data were analysed using content analysis, descriptive statistics, and variance analysis. Introducing dairy breeding technologies reduced women's control over milk incomes in two ways. First, improved breeds led to women and men participating in milking, previously carried out solely by women. The increased profitability of the dairy enterprise raised the outlook and status of some chores related to dairy husbandry. This shift, although linked with women's economic empowerment and gender-equal distribution of household responsibility, resulted in the transfer of milk income from women to men in most cases. This demonstrates a marked shift in women's traditional roles away from exclusive contributors to household nutrition to dependents of their husbands to meet household nutritional needs. In most survey responses (99.9 %), the study showed that technological improvement led to milk increase. The milk increase did not, however, necessarily correspond to higher income for farmers, as the milk market would easily oversaturate, culminating in low prices. The impact of shifting gender norms and dynamics on household food security and livelihoods can be positive and negative, with its severity varying based on the household type and marital status of the dairy farmer. Therefore, to maximise transformative outcomes, innovative technologies should be customized to meet the requirements of different gender groups while considering societal and gender norms. Furthermore, providing training on further innovations could mitigate any consequences resulting from current advancements.

Keywords: Animal breeding, gender dynamics, gender norms, smallholder dairy

Contact Address: Immaculata Okeke, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Steckfeldstraße 24, 70599 Stuttgart, Germany, e-mail: immaculata.okeke@uni-hohenheim.de

Shifting gender roles in agriculture: Estimating the impact of a women-centric R&D programme in India

Vijesh Krishna[1], Subash Surendran Padmaja[2], Monish Jose[3], Wasim Iftikar[1], Prakashan C Veettil[4]

[1]*International Maize and Wheat Improvement Center (CIMMYT), Sustainable Agri-food Systems, India*
[2]*Univeristy of Bonn, Center for Development Research (ZEF), Germany*
[3]*Kerala Institute of Local Administration (KILA), India*
[4]*International Rice Research Institute (IRRI), India*

With the rapid structural transformation of the economy and the increased outmigration of male farmers, Indian agriculture has been increasingly feminized in the recent past. Nevertheless, the research-and-development (R&D) programmes in the field of agricultural and rural development often neglect to address the unique challenges that women farmers face in crop production and marketing. Furthermore, gender-sensitive socioeconomic research has revealed the intricate nature of intra-household decision-making and resource allocation, and that increased involvement of women in agriculture does not invariably ensure a better livelihood for them, especially when patriarchal norms and family relations remain strong. Women are often involved as unpaid family laborers than farm managers. Against background, the present study estimates the effects of an inclusive extension programme for women farmers of Odisha State, India. We aim to examine the changes in women's empowerment status as a result of their participation in a women-centric R&D initiative on sustainable intensification of rice-fallow systems. Maize was introduced with the help of demonstration trials, field days, and farmer training sessions, which were mediated through women's self-help groups (SHGs) to increase farm-household income in Mayurbhanj District. Using a cross-sectional dataset of 1,005 women farmers, the effects of the demonstration trials on maize adoption were obtained. Further, using a quasi-experimental approach with instrumental variables, we obtained the impact of maize adoption on women's empowerment, captured using the Abbreviated Women's Empowerment in Agriculture Index (a-WEAI). The analysis provided three broader lessons and implications for inclusive extension programmes on sustainable intensification of agricultural systems. First, targeted dissemination of new cash crops like maize is found to enhance women's agency in multiple ways. Second, implementing the R&D projects through SHGs is found to enhance women's active participation in group activities,

Contact Address: Vijesh Krishna, International Maize and Wheat Improvement Center (CIMMYT), Sustainable Agri-food Systems, ICRISAT Campus, 502324 Hyderabad, India, e-mail: v.krishna@cgiar.org

which could improve their agency and control over production resources. Finally, gender-sensitive technology development and dissemination require a multi-pronged strategy to guide the agricultural R&D system for modifying institutional frameworks and mindset to promote gender-intentional sustainable intensification interventions. Increased investment and research focus are necessary to better understand and integrate gendered technology preferences into the broader sustainable intensification framework.

Keywords: Feminisation of agriculture, inclusive extension, maize

Nutrition, gender and social cohesion effects of commercialisation of African indigenous vegetables on smallholder farmers

Christoph Kubitza[1], Sarah Hackfort[1], Caroline Stokes[1], Cornelia Rauh[2], Ann-Marie Kalla-Bertholdt[2], Arnold Opiyo[3], Susanne Huyskens-Keil[1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*
[2]*Technical University Berlin, Germany*
[3]*Egerton University, Kenya*

The interdisciplinary research project "Social Cohesion, Food & Health - Inclusive Food System Transitions" (IFST) aims at advancing research on food system transitions focusing in particular on interactions with social and societal issues. In the framework of the IFST project, our case study on the nutrition-sensitive value chains of African indigenous vegetables (AIVs) analysed the commercialisation of these crops in Kenya. Using household fixed-effects models, we find that smallholder farm households' income increased significantly between 2016 and 2022 with AIV commercialisation. We analyse three potential trade-offs related to nutrition, resource sharing and solidarity, and women empowerment. We find that commercialisation did not negatively affect smallholders' nutrition outcomes but did not improve them either. In terms of community solidarity and resource sharing, our results are ambiguous. While we find that sharing AIV for free decreased with commercialisation, we find no consistent and significant evidence that solidarity indicators changed over time with AIV commercialisation. We relate this to our finding from the FGDs that there is no unidirectional effect of commercialisation on solidarity, but rather multiple and sometimes opposing mechanisms at work. Lastly, we observe an economic empowerment of women that we relate to women's individual and collective strategies as well as their retention of control over AIV marketing and profits. Yet, AIV commercialisation does not contribute to a redistribution of land rights or labor; instead, it increases women's labour burden. Overall, with rather favourable social and economic effects for smallholder farmers, these emerging nutrition-sensitive value chain of AIV could be an important instrument to reduce hidden hunger in sub-Saharan Africa due to their high densities of important micronutrients. However, this potential is threatened by high food losses. We analysed the extent of quantitative as well as nutritional food losses along the AIV supply chain based on a comprehensive literature review. Our results suggest high food losses for various nutrients during production and marketing, but also a lack of detailed studies on nutritional losses for AIV in the supply chain.

Keywords: African underutilised vegetables, Kenya, micronutrients, smallholder farmers, supply chains

Understanding territorial bioeconomy systems: The case of a rural women's community-based organisation in Colombia using biodiversity for the production of plant-based natural products

Daniela Mojica Lopez, Ricardo Vargas-Carpintero

University of Hohenheim, Dept. Biobased Resources in the Bioeconomy, Institute of Crop Sciences, Germany

The urgent need of balancing biodiversity conservation and its use as a source of livelihood options for rural inhabitants has gained increasing attention in the context of a growing biobased economy in rich biodiverse countries. One outstanding case is represented by the Guapi rural women's community enterprise, 'Ríos Unidos'. This community-based organisation is situated in Guapi, Cauca, in the Colombian Pacific. One of its production lines is Chanzará Products, where wild plants are transformed into phytotherapeutic products, employing traditional knowledge and techniques. Within the Chanzará product line and throughout the practical experience of the organisation, different needs that can be converted into upgrading opportunities have been identified. For instance, the improvement of technical aspects in product formulation and the determination of fair product prices are key strategies. Given the territorially-embedded nature of this organisation, a community enterprise, the transversal consideration of the social dimension is essential. Hence, this study conducts a quantitative and qualitative study with a systems approach of the Chanzará Product line. This is carried out through a multidimensional analysis covering the economic (i.e., value added) and technical perspectives (product formulation), in a context where traditional knowledge and handicraft elaboration are the building blocks of the production system. By means of participatory methods such as net mapping, semi-structured interviews, and observation, the organisational structure and the values associated to the products are elucidated. Additionally, the distribution of economic value along the value chain was analysed using the commercial margin calculation. Two key upgrading strategies and actions were identified. First, an experimental design, execution, and evaluation of product formulation, namely a facial cream, was carried out following a participatory action research (PAR) approach. This resulted in the co-creation of two additional items for the facial line, a tonic and a serum, in addition to optimising the facial cream. A second action was the standardisation of the formulations and procedures for the nine Chanzará Products. This study contributes to generating empirical evidence of bottom-up initiatives dedicated to the sustainable use of biodiversity and identifying success factors and improvement possibilities that can be replicated in other cases.

Keywords: Bottom-up approaches, community based enterprises, participatory action research, phytotherapeutic products, wild plants

Contact Address: Daniela Mojica Lopez, University of Hohenheim, Dept. Biobased Resources in the Bioeconomy, Institute of Crop Sciences, Im chausseefeld 7 zi 6341, 70599 Stuttgart, Germany, e-mail: mojicalopez87@gmail.com

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Gender gap in rice productivity: Micro-evidence from Myanmar

Nandar Aye Chan, Orkhan Sariyev, Manfred Zeller

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Gender equality in agriculture is critical to ensuring food security and economic development. Numerous studies have estimated the gender gap in agricultural productivity in many developing countries. The magnitude of the gender gap in crop productivity in Myanmar has not been evaluated in the literature. This article provides empirical evidence of the gender gap in rice productivity in the Ayeyarwady Delta Region, Myanmar using a detailed gender-disaggregated household and plot-level survey dataset (2014) from the IRRI rice project. This article investigated the limitations of existing literature in three different ways. First, this study used regionally represented crop-specific micro-level data. Second, the study separately estimated the gender gap in dry and wet seasons to address seasonal variation, and considered the heterogenous effects of marital status and locational variation. Third, this study also assessed jointly-managed plots, which are generally excluded in most previous studies. The Oaxaca–Blinder mean decomposition approach was used to identify the causes of gender differences in monsoon and summer paddy productivity. Our empirical findings show that female managers are 7.1 % less productive than male managers, particularly in monsoon paddy production, after controlling for observed factors; however, the magnitude of the summer yield gap (2.79 %) between men and women is small and insignificant. The structural effect (95.77 %) rather than the endowment effect (4.37 %) statistically explains the gender gap in monsoon paddy productivity, suggesting that despite having equal inputs access, men and women would have different productivity levels. Joint managers are 7.04 % more productive than female managers and 4.25 % more productive than male managers, particularly in summer paddy production. It shows that seasonality affects gender productivity disparity. The results of marital status heterogeneity show that divorced women account for a large portion of the productivity differential among non-married women managers. Initiatives to eliminate the gender gap in rice yield in Myanmar should pay attention to the unique requirements and obstacles women encounter throughout different seasons and tailor their interventions accordingly.

Keywords: Agricultural productivity, decomposition, gender, Myanmar, rice

Contact Address: Nandar Aye Chan, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), 70593 Stuttgart, Germany, e-mail: chan.nandar@uni-hohenheim.de

Women farmers' strategies to enhanced cocoa production: An Ivorian perspective

Claudia Coral[1], Bonna Antoinette Tokou[1], Franziska Ollendorf[1], Constant Yves Adou Yao[2], Stefan Sieber[1], Katharina Löhr[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany*
[2]*University Félix Houphouët-Boigny, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire*

In recent years, much has been done to promote equal human rights and financial independence for women cocoa producers. Nevertheless, women's role in cocoa farming households remains largely unrecognised. A focus on sex-disaggregated statistics leads to gender-related biases associated with imbalanced or incomplete representation of population groups and biased ways in which gender information is elicited. To overcome knowledge gaps on gender, this study focuses on Ivorian women cocoa farmers. Female-headed households in Côte d'Ivoire own, on average less land compared to male-headed households. Nonetheless, women's land tenure is a highly dynamic issue, and in recent years a growing number of female-headed households in cocoa-producing communities has been observed. Besides, female-headed households show an increasingly higher diversification in their cocoa farms. Based on 40 narrative interviews with female cocoa producers and representatives of producer associations, we aim to understand female-headed household farming and diversification strategies and their current challenges and opportunities related to their agricultural activity. Narrative interviews are a means of collecting women's own stories about their experiences as cocoa producers. The results of this study give insights into socio-cultural factors affecting women's participation in the Ivorian cocoa value chain, differentiated social needs, and strategies to overcome constraints. Land access, access to finance and labour, and high illiteracy rates are crucial issues limiting women's participation in the cocoa value chain. However, due to their increasing interest in agriculture and economic independence, and entrepreneurial skills, women have developed strategies to overcome constraints such as organisation, diversification, and gender awareness raising.

Keywords: Cocoa, diversification, gender, human rights, social inclusion

Contact Address: Claudia Coral, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Müncheberg, Germany, e-mail: claudia.coral@zalf.de

Gender roles in agroforestry: Challenges and opportunities in Dodoma region, Tanzania

Mahlet Degefu Awoke[1,2], Katharina Löhr[2,1], Marcos Lana[3], Johannes Michael Hafner[1,4], Anthony Kimaro[4], Stefan Sieber[1,2]

[1]Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

[2]Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany

[3]Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden

[4]World Agroforestry (ICRAF), Tanzania Country Programme, Tanzania

This study evaluates the gender roles in agroforestry (AF) technologies in the semi-arid Dodoma region of Tanzania, specifically focusing on women's contribution to tree intercropping combined with different soil and water harvesting technologies. We assessed various factors highlighting women's involvement in farm activities, allocated land for AF, decision-making (e.g., crop type selection and farm income control), land entitlement and ownership, and perception of the level of AF integration with indigenous knowledge. Using stratified random sampling, between August and September 2022, 315 households (HHs), consisting of 167 females and 148 males, from five villages were interviewed. Out of these, only 21 % were female-headed HHs. The findings indicate a difference in land allocation for AF technologies between male-headed and female-headed HHs, with male-headed HHs significantly ($p < 0.05$) allocating more land to AF. Additionally, only 22 % of females are entitled to land. The study also finds a significant association ($p < 0.05$) between gender and the perception of the level of integration of AF with indigenous knowledge, with male farmers perceiving a higher level of AF integration (30 %) than female farmers (17 %). Female farmers mentioned high capital cost, lack of skilled labour, and lack of know-how as factors for low AF integration with local knowledge. Although it was not our study's primary objective, the study revealed a lack of gender diversity in the agricultural extension services provided in the region, as there were no female extension workers in the five study villages. Despite this, female farmers were involved in a greater diversity of farm activities than male farmers, and decision-making for crop type selection and farm income control was mainly joint. Programs prioritising the inclusion of women in AF technologies are crucial to ensure sustainable and equitable agricultural development, thereby improving rural livelihoods. Empowering female farmers by addressing land entitlement issues, increasing credit access to female farmers, and involving more female agricultural extension workers are key to enhancing women's involvement in promoting the adoption of AF technologies and improving gender equity in the agriculture sector in the study region.

Keywords: Agroforestry, female farmers, indigenous knowledge, land entitlement

Contact Address: Mahlet Degefu Awoke, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder Straße 84, 15374 Müncheberg, Germany, e-mail: mahidege@gmail.com

Farmers perception of female extension services in Ghana

KWABENA BUABENG, KATHARINA LÖHR, STEFAN SIEBER

Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries" (SusLAND), Germany

The recent food crisis has emphasised the need to support agricultural development. Women play a significant role in agriculture in many parts of Africa as they are the principal producers. In Ghana, it is estimated that female farmers are accountable for over 70 percent of total food production. Women are the most important actors in the food chain which starts from farm production, market and most importantly distribution of food within the household. However, presently, female farmers receive only a fraction of the inputs and support that their male counterparts receive. One of such inputs is extension services. This disadvantage further worsens the bias towards male farmers subsequently preventing efforts being made to offer agricultural services to women. Therefore, supporting female farmers is key to agricultural development, food security and the sustainable improvement of rural livelihoods. In Ghana, the public sector is the key provider of extension services to farmers. It is underfunded and lacks coordination which leads to underserved farming populations. The study was conducted in two communities in the western North of Ghana. The study consisted of a total sample of 80 smallholder farmers, of which 40 are female and 40 male. This study focuses on the presentation of major descriptive findings from the quantitative research. The objective of this study is to investigate why women are disadvantaged in agricultural extension work and to identify the problems regarding ineffectiveness of extension programmes among women as well as recommend measures for improvement. Field data was analysed using various statistical tools including frequencies percentages. The study is expected to ascertain whether agriculture extension services in the communities were adequate and delivered equitably. It is expected that the agriculture extension programmes should address the specific needs, preferences and interest of the men and women farmers for its equitable accessibility.

Keywords: gender equality, extension services, food security

Contact Address: Kwabena Buabeng, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries" (SusLAND), Aristotelessteig 2, 10318 Berlin, Germany, e-mail: buabengk@gmail.com

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Agroecology as a choice of farming practice for women household members and restoration potentials: A case of Lake Chamo catchment, southern Ethiopia

Shibire Bekele Eshetu[1], Marcos Lana[2], Stefan Sieber[1], Katharina Löhr[1]

[1]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany*

[2]*Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden*

Agroecology is one of the promising solutions and is currently promoted to deal with current challenges like biodiversity loss and climate change. Particularly on smallholder farmers' land where securing households' food consumption is a priority. The objective of this study is to explore how agroecology-based homestead agroforestry system is contributing to forest landscape restoration (FLR) and providing financial equity for women. The study used qualitative data through focus group discussion (FGD) with a total of 32 participants (8 per FGD) discussed with men and women separately. Participants were asked to mention the reason they are practicing the agroforestry system in their homestead as well as subsequent questions on agroforestry practices. The practice of agroecology with various components on their homestead is the most preferred land use practice by women than men. Most participants indicated securing household food consumption from the *Ensete ventricosum* (enset), vegetables, and other perennial crops they integrate into the agroecology practice is their primary objective for the practice. Furthermore, practicing agroecology in their homestead is an inherited societal practice. Interestingly, the cash earned from land use products is shared based on gender. Men are privileged to handle crop products, plantation and livestock whereby most products sold from the homestead are left for women. This is due to their full engagement in the management, and direct cash earning is possible from components like a coffee leaf, *Moringa oleifera* powder, products from enset and vegetables. Even though the women spend the money they have earned from their homestead for the whole household members' need, it gives them financial freedom and security. It has been indicated that indigenous tree species like *Cordia africana*, *Terminalia brownii* and *Junipuros procera* are the most preferred tree species by both men and women. This will provide a chance to integrate these tree species into the agroecology practice. The integration has great potential in implementing FLR through tree-based restoration practice in the land use system. The study concludes that agroecology practice can potentially solve income inequality between women and men farmers while solving the trade-off between FLR using monocrop plantations and securing household food security.

Keywords: Agroecology, FLR, food security, homestead agroforestry, tree based restoration, women

Contact Address: Shibire Bekele Eshetu, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Eberswalder Strasse 84, 15374 Müncheberg, Germany, e-mail: bekeleshibire@yahoo.com

To what extent do the work organisation and the role of women determine farm trajectories in the Colombian and Brazilian Amazon?

Andrés Vega-Martinez, Nathalie Cialdella, Andrieu Nadine

CIRAD Center for International Cooperation in Agricultural Research for Development, UMR INNOVATION, France

The development of agriculture in the pioneer fronts in tropical forest is complex given the tensions that may occur between farm management, forest preservation and socio-economic development. Agriculture worldwide is developed by small family farmers. In these farms, their functioning, their organisation of family work and, specifically, the role of women affect individual trajectories and forest transition processes (degradation, deforestation, regeneration, conservation).

From a systemic agronomy approach, we developed a new methodology to analyse farm trajectories and their bifurcations in pioneer fronts. Farmers were sampled based on degradation, deforestation, regeneration and conservation hotspot in Guaviare, Colombia and Paragominas, Brazil. Through semi-directed interviews, we analysed the role of women and the work organisation of family that allow us to identify the factors of sustainable trajectories. In addition, we analysed the territorial factors (public policies, roads, markets) that have had an effect on the trajectories. Finally, in order to determine whether agroecology is a solution for sustainable development in the Amazon, the farm trajectories are reviewed using a grid of agroecological principles. Our results showed that women play a fundamental role (often invisible) in beginning trajectories that leads to forest regeneration and conservation. Women farmers are also a fundamental actor in pioneering fronts for agroecology. It was found that the management strategy of intensification can lead to regeneration or conservation of forest, as opposed to a strategy based on the expansion of the farm, which in its early stages degrades the forest. The type of management may depend on the stage of the front pioneer (beginning, active, consolidated).

Both local government and development programmes play crucial roles in preventing deliberate bifurcations in farm trajectories that lead to degradation and deforestation (such as peak workloads, poor health care systems or extreme poverty situations). In conclusion, we identified the factors that must be addressed in pioneer fronts to foster farm sustainable trajectories that are a key for building sustainable Amazon territories. However, there is not only one solution and the design of sustainable pathways (prospective studies) is fundamental to support a transition to sustainable territories.

Keywords: Agricultural trajectories, agroecological transition, family farms, pioneer front, transitional pathways

Contact Address: Andrés Vega-Martinez, CIRAD Center for International Cooperation in Agricultural Research for Development, UMR INNOVATION, 73 rue jean-François breton bureau 117, 34398 Montpellier, France, e-mail: andres.vega@cirad.fr

Hidden pathways: Approaches to understand intra-household gender relations and climate adaptation in Kenya dairy systems

Tanaya DuttaGupta, Renee Bullock, Philip Miriti

International Livestock Research Institute (ILRI), CGIAR, Sustainable Livestock Systems, Kenya

The transformation of livestock systems towards sustainable climate smart systems will generate multiple trade-offs and synergies. In this paper, we describe how gender relations shape, and are shaped by, climate adaptation innovations, specifically the uptake of innovations in dairy producing households in Western Kenya. Our research complements a producer-led scaling intervention in which positive deviants are those who, all else being equal, outperform their neighbours. These 'adaptation pioneers' then lead the scaling of climate smart feed and fodder innovations in their communities. However, intra-household dynamics surrounding uptake of innovations often are uneven and can reinforce inequitable distribution of benefits and burdens. We develop a positive deviance framework to identify common and 'hidden' patterns and pathways in intra-household gender relations related to dairy innovations, such as decision-making surrounding income and labour. Qualitative data was collected through 20 sex disaggregated focus group discussions, 10 key informant interviews, and field observations in Nandi and Bomet counties over multiple visits in 2022–2023. Using vignettes, we explore what 'typical' and less common, or 'deviant' household relations are, and whether such deviations are socially acceptable. Thematic analysis was performed in NVivo using iterative deductive and inductive approaches. We find that most households are patriarchal- men are the primary decision-makers and, unsurprisingly, this is generally also socially acceptable in the community. However, both women and men desire more equitable relations and outcomes in their households, but due to social norms that guide what is socially acceptable in the community, these relationships are not discussed openly in society, especially because they undermine men's roles as heads of household. Married women also negotiate and navigate decision-making spaces, often in hidden ways. This research generates insights into methodological approaches to reveal complex yet oversimplified dimensions of gender relations, such as who has agency, and when and how agency is negotiated. Our findings highlight the potential trade-offs and synergies that may occur through producer-led scaling and sets a foundation for the design of gender responsive scaling approaches that can foster synergies in socially equitable climate adaptation strategies and outcomes.

Keywords: Climate smart livestock systems, dairy innovations, intra-household gender relations, Kenya, positive deviance approach, producer-led scaling, trade-offs and synergies

Contact Address: Tanaya DuttaGupta, International Livestock Research Institute (ILRI), CGIAR, Sustainable Livestock Systems, International livestock research institute Box 30709, 00100 Nairobi, Kenya, e-mail: t.duttagupta@cgiar.org

How to foster inclusive food systems? Approaches to assessing social vulnerability and foster social equity

Online posters

Assessing flood vulnerability for social inclusion and disaster preparedness in Kerala's farming communities

Dhanusha Balakrishnan[1], Christoph Funk[2], Seema Balan[1], Archana Raghavan Sathyan[1]

[1]*Kerala Agricultural University, College of Agriculture, Dept. of Agricultural Extension, India*
[2]*Justus-Liebig University Giessen, Center for International Development and Environmental Research (ZEU), Germany*

In recent years, natural disasters have significantly impacted both developed and developing countries, claiming lives and disrupting economic and social structures. Floods and landslides, accounting for 47 % of all weather-related disasters, have been particularly devastating, and affecting 2.3 billion people worldwide. India, especially its southern state of Kerala, has been heavily affected by flooding due to topography and socio-economic factors. The southwest monsoon's recent changes have led to severe flooding and landslides in Kerala. Despite farmers in Kerala being frequently impacted by floods and landslides, there is a lack of studies on their vulnerability, particularly concerning socio-economic aspects. Assessing farmers' vulnerability to natural disasters is crucial for reducing disaster-related risks and ensuring livelihood sustainability. In this study, we evaluate the vulnerability of Kerala's farmers using a societal vulnerability index for floods and landslides (SVIFL). Examining farmers' vulnerability to floods and landslides by considering social, physical, environmental, and economic dimensions is essential for understanding how hazards affect individuals and communities. To develop the index and enable regional comparison, we collected data from 520 farm households in Kerala's highlands (Wayanad and Idukki) and lowlands (Alappuzha and Pathanamthitta). We selected 80 location-specific indicators for the vulnerability assessment. SVIFL results indicate that Kerala's highlands are more vulnerable to flooding and associated landslides than the lowlands. Among the four components analyzed, economic vulnerability ranks highest, followed by environmental and physical vulnerability. Interestingly, social vulnerability has the lowest susceptibility to natural disasters in Kerala. Consequently, the development of SVIFL serves as a foundation for assessing the vulnerability of farming communities, which bear the brunt of climate change and natural disasters.

Keywords: Farmers, floods, landslides, vulnerability assessment

Land tenure and agricultural crimes: Empirical evidence from rural Tanzania

Nelson Albert Ochieng[1], Ulrike Grote[1], Arnab K. Basu[2]

[1]*Leibniz University Hannover, Institute for Environmental Economics and World Trade, Germany*

[2]*Cornell University, Dyson School of Applied Economics and Management, United States*

Land tenure and agricultural crime are major concerns in sub-Saharan Africa (SSA). While around 26 % of landholders perceive their land tenure insecure, crime has been reported as one of the country's most pressing issues. There is a lack of empirical linkage between land tenure and agricultural crime. This article provides evidence of agricultural crime, a subject that has received little attention in the literature so far by giving answers to the following questions; (1) who is more vulnerable to agricultural crime victimisation between individual and family land owners? (2) Does secure land tenure decrease agricultural crime? This study uses primary household data collected in 818 households from rural Tanzania. Two dimensions of crime (dummy of crime victimisation and crime frequency) were investigated. In estimation we used double lasso regression; a double-selection lasso logistic model for victimisation, and a double-selection lasso poisson model for crime frequency. We also used propensity score matching (PSM) in measuring the effect of land tenure and tenure security on agricultural crime. The results show that 35 % of households are victimized at least once in a year. We find that on average crime results in a loss of 95.8 USD from agriculture per victimized household per annum. Most crimes take place between April and August which is the harvesting period in the study area, and 63 % of crime events happen in the fields. Furthermore, individual landowners have an 8–12 % higher probability of being victimized compared to family landowners. Similarly, individual landowners are victimized more frequently than family landowners. In addition, land tenure security (land title) significantly reduces the probability of crime victimisation and crime frequency. Promoting rural safety and lessening the bureaucratic process in the provision of certificates of customary rights of occupancy (CCROs) in rural Tanzania are integral to reducing agricultural crime events.

Keywords: Agricultural crime, agriculture, land tenure, land tenure security

Contact Address: Nelson Albert Ochieng, Leibniz University Hannover, Institute for Environmental Economics and World Trade, Königsworther platz 1, 30167 Hannover, Germany, e-mail: ochieng@iuw.uni-hannover.de

Positive grounds for agroforestry-based systems in Tunisia to transform to more equitability and inclusiveness

Zied Idoudi[1], Aymen Frija[1], Veronique Alary[2,1], Mourad Rekik[1], Hatem Cheikh[1]

[1]*International Center for Agricultural Research in the Dry Areas (ICARDA), Tunisia*
[2]*SELMET, CIRAD, INRAE, Institut Agro, Université Montpellier, France*

Agroforestry-based food systems play a critical role in many dryland regions of the word, including Tunisia. These farming systems offer a range of benefits such as diversification of food and income resources for local communities, biodiversity conservation, and environmental resilience. Fig trees, olives, carob, and honey are common features of these Mediterranean agroforestry landscapes, and their produce is a traditional staple in many cuisines. In Tunisia, fig trees are often grown alongside other crops, such as olives, and under agroforestry-based farming systems that integrate crops and trees. However, in the particular case of Kesra region, in central Tunisia, where agroforestry-based farming systems prevail, there are many signs of degradation and environment stress (resources scarcity, poor waste management, biodiversity loss of figs and olives, decreased food resources for bees, declining health of soil, decreased water availability and natural springs, etc.) including market competition. While this system provides a diversity of food products, the opportunity for valorisation outside the usual markets remains also low.

A multistakeholder platform (MSP) engaging the community members of Kesra region around the above problems was set in 2022/2023. The MSP was conceived on the co-building of a shared vision of the local systems over the next decade that fits to the agroecological principles of synergies, economic diversification, social value, and connectivity. Through the MSP, a context-specific sociotechnical innovation bundle was co-designed and being co-implemented as a mean to foster agroecology transformation around the agroforestry-based farming systems in Tunisia. The study shows that an inclusive participatory approach involving food system actors for the co-design of alternative agroforestry systems can lead to co-defining context specific innovations and technologies which offer immense potential for promoting food system transformation towards equity and inclusivity, and provide multiple benefits such as soil conservation, increased biodiversity, and improved food security

Keywords: Agroforestry, collective action, food systems, innovation bundles, multistakeholder platform, social inclusion

A conceptual framework of living labs for people: Fostering innovations for low-emissions food systems and social equity

Ryan Nehring[1], Birgit Habermann[2], Wei Zhang[3], Upeksha Hettiarachchi[3], Thomas Falk[4], Anne Rietveld[5], Eva Valencia Lenero[6], Lennart Woltering[6]

[1]*International Food Policy Research Institute, Natural Resources and Resilience Strategies Unit, United States*

[2]*International Livestock Research Institute (ILRI), Sustainable Livestock Syst., Kenya*

[3]*International Food Policy Research Institute (IFPRI), United States*

[4]*International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Germany*

[5]*The Alliance of Bioversity International and CIAT, Kenya*

[6]*International Maize and Wheat Improvement Center (CIMMYT), Systems Science, Mexico*

This paper provides the conceptual basis for what we call living labs for people (LL4P). We define LL4P as an inclusive and diverse space for people to envision, co-design, test, demonstrate and advance their socio-technical innovations and associated modes of governance within a facilitated organisational structure. Our specific aim with LL4P is to facilitate locally developed innovations for low-emission food systems that address social equity in four target countries: China, Colombia, Kenya and Vietnam. This conceptual paper outlines a framework to guide activities in each of those four countries. The LL4P draws on the living lab literature but tailors existing approaches for food systems in developing countries. Four country teams, made up of CGIAR researchers and national partners, adapt LL4P to the specific socio-ecological and cultural context and in line with each country's mitigation policy such as the nationally determined contribution (NDC). Therefore, while this conceptual paper provides a rationale, framework and a set of guidelines, it will also incorporate distinct approaches and learnings from each of the four target countries. The key components included within the LL4P concept are scenarios, governance, facilitation, and a learning alliance to plan, enable, and enact innovation agenda setting for transformative change. Each of the institutional components combine to address the following principles: 1) gender and social inclusion; 2) the co-production of knowledge and technology; 3) institutional stability; participatory governance; 4) common benefits for participants and; 5) co-benefits contributing to the sustainable development goals. The practical experience from applying this framework in the four case studies will generate learnings about alternative pathways for other

Contact Address: Ryan Nehring, International Food Policy Research Institute, Natural Resources and Resilience Strategies Unit, 1201 I street nw, 20005 Washington, United States, e-mail: r.nehring@cgiar.org

LL4P focused on low-emission food system development and social equity. We understand that socio-ecological transitions, rooted in the food system, need to be based on building alliances between development organisations, governments and local stakeholders. By extension, innovations should not be top-down interventions from a select few, but rather, the result of trans-disciplinary and multi-sectoral collaboration agendas. The LL4P concept is based on the process and platforms to achieve this common understanding and joint work.

Keywords: Climate change, equity, food systems, innovation, living labs, mitigation

Operationalizing social equity in agricultural research

Eva Thuijsman, Jens Andersson, Katrien Descheemaeker, Ken Giller

Wageningen University and Research, Plant Production Syst. Group, The Netherlands

Studies that apply multi-indicator frameworks to assess the sustainability of farming systems have tended to focus narrowly on production and the environment, neglecting the social dimension of sustainability. This study addresses this gap by examining the specific challenges involved in operationalizing social equity in a large-scale research-for-development project that applied a comprehensive sustainability framework to assess impacts of farming technology interventions in northern Ghana. Our preliminary analysis of project documentation and interviews with project staff revealed that social equity is conceptualised and operationalized via related concepts such as farm household diversity, social differentiation, poverty reduction, gender and inclusivity, which are sometimes used interchangeably. Practical entry points to engage with social differentiation included farm household typologies and data disaggregation by farm type or gender. Typologies were regarded as an important tool to evaluate the fit between technology and intended beneficiaries and to identify farm households to target in scaling activities. Key challenges arose as farm household types could be dynamic, difficult to identify in the field, and difficult to adopt by scaling partners. Furthermore, the disciplinary backgrounds of project staff favoured quantitative approaches to describe and compare farm types, but these did not necessarily reveal the differentiating mechanisms that a technology might put in motion, nor whether these were problematic or not. The right expertise distribution and task division among staff are therefore crucial. We assessed the multiple system boundaries within which equity was considered in the project, and captured reflections on the conduciveness of integrating a social equity perspective across-the-board or in distinct, focused research activities. The insights generated throughout this learning trajectory of operationalizing social equity can provide guidance for future research-for-development projects in their steps towards equity.

Keywords: Farm typology, inequality, inequity, sustainability assessment

Contact Address: Eva Thuijsman, Wageningen University and Research, Plant Production Systems Group, Bornsesteeg 48, 6708PE Wageningen, The Netherlands, e-mail: eva.thuijsman@wur.nl

Unpacking farmer diversity to support inclusive climate-resilient agricultural practices

Carla Cronauer[1], Naima Lipka[1], Julia Tomalka[1],
Chiara Sophia Weituschat[1], Roopam Shukla[2]

[1]*Potsdam Institute of Cimate Impact Research, RD2 - Cimate Resilience, Germany*
[2]*Indian Institute of Technology, Centre of Excellence in Disaster Mitigation and Management, India*

Across sub-Saharan Africa, smallholder farmers already face numerous risks to agricultural production. With destructive cyclones and severe droughts, Madagascar has been hit especially hard in recent years. Climate change is exacerbating existing vulnerabilities and is expected to disproportionately affect smallholder farmers, highlighting the need for climate adaptation in the agricultural sector. However, smallholder responses to climate change are not uniform. The adoption of climate-resilient agricultural practices is influenced by heterogeneous social, cultural, agronomic, economic, and institutional conditions. Hence, homogeneous representations of smallholder farmers can lead to further marginalisation and exacerbate existing vulnerabilities, in particular among women, elderly and illiterate people. In this study, we seek to capture the diversity of farm households and understand the adoption of climate-resilient agricultural practices, with particular attention to groups in vulnerable situations. Typology construction provides an efficient method to understand farm(ing) household diversity by delineating groups with common characteristics. Furthermore, it is a useful tool to improve both up- and out-scaling of climate-resilient agricultural practices. The proposed study will be based on household survey data collected in Atsimo Atsinanana, Anosy and Androy in Madagascar in April and May 2023. In a first step, we conduct a literature review and establish a typology framework, which we validate with local experts. In a second step, we use a statistical typology approach, a combination of principal component analysis for necessary data reduction and a cluster analysis to delineate different farm household types. Furthermore, we will use descriptive statistics to link the different farm household types to the adoption of climate-resilient agricultural practices. In terms of the results, we expect differences regarding asset ownership, gender and household composition, access to credit and education, as well as other household characteristics, highlighting the need for considering the nuances within farming communities to ensure inclusive adaptation planning for climate-resilient food systems.

Keywords: Adaptation, climate change, diversity, farmer types, food systems, gender, intersectionality, Madagascar, vulnerability

Effect of COVID-19 on forest dependent households in Kenya: Does access to forest resources act as a safety net?

Robert Mbeche[1], Josiah Ateka[1], Ulrike Grote[2]

[1]*Jomo Kenyatta University of Agriculture and Technology, Dept. of Agricultural and Resource Economics, Kenya*

[2]*Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Germany*

The disruption of COVID-19 on livelihoods globally has been undeniable, especially among marginalised groups. While existing evidence from SSA shows that forest communities are disproportionately affected by shocks, the understanding on how they were affected by COVID-19 and their corresponding coping strategies remains limited. We use a panel dataset of rural forest dependent households obtained from two survey waves during 2018–2022 (746 households) in Western Kenya to assess the effect of COVID-19 on livelihood activities and resultant coping strategies. We then analysed the data using descriptive and econometric techniques. Results show that COVID-19 negatively affected household livelihoods, including loss of wage employment for household members, decreased agricultural incomes, restricted access to farm inputs and agricultural markets. Households experienced a decline of household incomes from KES 104,305/annum in 2018/19 ($802) to 39,588 (US$ 304) representing a 37 % drop. Key reactions of households in the study area to COVID -19 shocks include; extracting forest food products such as vegetables, honey and wild fruits, reducing household expenses, subsistence agricultural production, taking up odd jobs, borrowing from relatives and use of household savings. The proportion of households that extracted forest products increased by 6 % from 2018–2022. Our findings show that the use of forest products helps poor households in cushioning against the effects of COVID-19 shocks. Forest products collection aids consumption smoothing while protecting asset depletion in the wake of covariate shocks. This makes the availability of forest resources a critical safety net. These findings suggest the importance of promoting sustainable resource extraction as a form of sustaining and cushioning households against future unforeseen occurrences.

Keywords: COVID-19, forest communities, Kenya, resilience, vulnerability

Contact Address: Robert Mbeche, Jomo Kenyatta University of Agriculture and Technology, Dept. of Agricultural and Resource Economics, P.O Box 62000-00200 , Nairobi, Kenya, e-mail: rmbeche@jkuat.ac.ke

ID 807

The impact of weather calamities in (semi)sedentary indigenous communities in the Philippines

Gretchen Gonzaga

University of Bonn, Center for Development Research (ZEF), Political and Cultural Change, Germany

The Sama Badjao people practised mobile boat-dwelling for hundreds of years and traditionally crisscrossed the waters of Southeast Asia. They considered the reefs and the sea as their home. Since the late 1960s, their challenging conditions–tightening border controls, continuous armed conflicts, gradual decline of fish, and restrictions on movement, led them to follow a (semi)sedentary lifestyle. One of the largest sedentarized Sama Badjao communities settled in the coastal area of Bato, Leyte, Philippines, where strong weather disturbances threatened them. One case was when super-typhoon Rai devastated the region on December 16, 2021. Rai was a category-five typhoon that brought massive destruction to the central and southern Philippines. This study aims to investigate how Sama Badjao experienced disasters and recovery efforts after a typhoon calamity. Fieldwork was conducted for ten months by utilising an ethnographic approach. Guided by the theory of otherness, findings revealed that the Sama Badjao experienced structural discrimination within the disaster recovery programme in the municipality. Their lack of social articulation as well as representation in the public sphere made it hard for them to demand or access whatever means of resources so they can bounce back from the disaster. This augmented their existing political and social issues making them more vulnerable to the impacts of climate change. Therefore, I suggest policymakers and development practitioners acknowledge Sama Badjao's right to self-determination by giving them a platform for social articulation. They should always consider their culture and include them in decision-making processes in designing policies and programmes for integration.

Keywords: Bajau, disaster recovery, indigenous peoples, Sama Dilaut, subaltern

Contact Address: Gretchen Gonzaga, University of Bonn, Center for Development Research (ZEF), Political and Cultural Change, Genscherallee 3, 53113 Bonn, Germany, e-mail: ggonzaga@uni-bonn.de

Is deforestation hindering refugee integration? The case of the Mantapala settlement in rural Zambia

Brigitte Ruesink, Steven Gronau

Leibniz University Hannover, Institute for Environmental Economics and World Trade, Germany

Refugee numbers are notably high in Africa and integration instead of repatriation is an increasingly popular approach. In order to ensure a successful and sustainable integration, it is essential to investigate long-term effects of refugees on the hosting area. As refugees usually arrive in large numbers, there is high pressure on forest stocks in the host country. On the one hand, space and materials are needed for housing in refugee settlements, and on the other hand, refugees require firewood and charcoal for daily life. Although literature on effects of refugees on their host environment is increasing, agent-based models, which enable a simulation of future developments, rarely focus on refugees' effects on their host community. This study applies an agent-based model to investigate the impact of refugees on deforestation in their host area. In the model, host and refugee households interact with each other, as well as the environment and this individual behaviour adds up to deforestation on a bigger scale. The paper aims (1) to identify how refugee settlements and host communities affect forest resources in developing countries, (2) to predict which settlement capacity is sustainable in the forest context and (3) to analyse how labour cooperation and the corresponding expansion of slash and burn agriculture affect the deforestation rate. The analysis utilises a 2018 dataset from a refugee hosting area in rural Zambia including 277 households. Secondary data on forest composition, contact probability, etc. complements the dataset. Preliminary results show the maximum sustainable yield of forest resources, as well as an effect of labour cooperation on slash and burn activities and the availability of these resources. The analysis enables the derivation of policy recommendations on building refugee settlements more sustainably in the future to counter deforestation and support integration.

Keywords: Africa, agent-based modelling, deforestation, forest management, host society, refugees, rural development, sustainability, Zambia

Contact Address: Brigitte Ruesink, Leibniz University Hannover, Institute for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: ruesink@iuw.uni-hannover.de

Violent conflict moderates food security impacts of agricultural asset transfers in Syria: A heterogeneity analysis using machine learning

Dorothee Weiffen, Ghassan Baliki, Tilman Brück

International Security and Development Center, Welfare program, Germany

Violent conflict is the main driver of food insecurity. Agricultural interventions are one of the key policy tools to strengthen the food security of households living in conflict settings. Yet, evidence on whether and how households respond to agricultural aid in such complex settings remains scarce, particularly given that violent conflict directly shapes how people make economic choices and decision-making. More specifically, the role in which conflict shapes the food security impact of agricultural support remains broadly unconfirmed. To address this knowledge gap, we analyse the short-term average and heterogeneous treatment effects of an agricultural asset transfer on food security in conflict-affected Syria. Building on a quasi-experimental design which compares treatment and control households before and two years after receiving support, we apply honest causal forest estimation to examine how violent conflict moderates treatment heterogeneity. As expected, our results show that agricultural asset transfers significantly improve food security in the short-term. More interestingly, we find that the intensity of the exposure to violent conflict is key in determining if and by how much households benefit from support. We find that households living in moderately-affected conflict areas benefited significantly from the agricultural intervention and improved their food security by 14 %, while those living in severely-affected conflict or peaceful areas did not benefit much. The positive effects at the intermediate level of violence were particularly strong for female–headed households. These findings underscore the complex and intricate role conflict plays in determining how agricultural aid translates to stronger household food security. Moreover, the results show that focusing only on studying average impacts in conflict and volatile settings conceals specific nonlinear variations in how households benefit from aid. At the policy level, moving away from one-size-fits-all programmes and designing conflict-sensitive and inclusive interventions ensure that no households are left behind.

Keywords: Agricultural intervention, asset transfers, food security, honest causal forest, impact evaluation, machine learning, Syria, violent conflict

Contact Address: Dorothee Weiffen, International Security and Development Center, Welfare program, Berlin, Germany, e-mail: weiffen@isdc.org

Silent voices in the oil and gas development in Uganda's Albertine Graben

Estellina Namutebi[1], Joost Dessein[1], Marijnen Esther[2]

[1]*Ghent University, Agricultural Economics,*

[2]*Wageningen University and Research, Sociology of Development and Change, The Netherlands*

Oil and gas development has promoted the lives of the elite in Uganda. Most of them seized land in the Albertine Graben to share in the economic gains of shale oil and gas at the extent of the people at the grassroot. Those at the grassroot are geographically the primary stakeholders in the oil and gas resource whose voices have been silenced by the unjust situations they are experiencing. They are the silent voices who have not been involved in the whole process of oil and gas development, yet the resources have existed in their ethnic region for ages. In addition to land grabbing, which has left most host community members homeless, the few scattered patches of land are infertile and not suitable for farming activities due to the decommissioning activities which were haphazardly done. The future of the host communities looks bleak because the exploration activities upstream stage have perturbed the ecosystem services. Despite being primary stakeholders, they are never involved in the decision-making of their ethnically natural resources. The 2008 Petroleum Policy well stipulated how the primary stakeholders and the environment will be protected, but the implementation and enforcement are poor. Using the grounded theory the paper sought to find ways in which host communities can build resilience using the perspective of environmental justice by claiming their autonomy as primary stakeholders and making the government accountable for its actions within the region. Consequently, the findings discovered that the host community's voice is not heard, for instance, women's voices are thwarted, yet they are the breadwinners of the communities of the Kibiro landing site in Hoima district. The men in this vicinity can no longer do the fishing activities as in the past because they are forbidden to do so. Thus the need for capacity building in developing a community resilience model using environmental justice.

Keywords: Development, oil and gas, silent voices

Contact Address: Estellina Namutebi, Ghent University, Agricultural Economics, Coupure links, 9000 Ghent, Belgium, e-mail: estellina.namutebi@ugent.be

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Shifting the paradigm on refugee-hosting landscapes: From land degradation to land restoration and resilience

Andrew Adam-Bradford[1], Mary Njenga[2], Ruth Mendum[3], Solomie Gebrezgabher[4], James Kinyua Gitau[5], Desta Woldetsadik[6]

[1]*Oxford Brookes University, Center for Development and Emergency Practice (CENDEP), United Kingdom*

[2]*CIFOR-ICRAF, Climate Change, Energy and Low-Carbon Development Theme and Refugee-Hosting Engagement Landscape Programme, Kenya*

[3]*Mendum Consulting, Penn State University (retired), Gender Equity through Agricultural Research and Education Initiative (GEARE), Ag Sciences Global, College of Agricultural Sciences, United States*

[4]*International Water Management Institute (IWMI), Ghana*

[5]*World Agroforestry (ICRAF), Kenya*

[6]*Wollo University, Dept. of Soil and Water Resources Management, Ethiopia*

In sub-Saharan Africa, refugee hosting landscapes are located in fragile ecological zones in arid and semi-arid areas. The low economic value and natural resource base of these sites is one reason these locations are selected for development into refugee camps and/or refugee settlements. The sites are characterised by high levels of land degradation, deforestation and loss of biodiversity due to invasive species infestations, such as Prosopis juliflora. Furthermore, if these sites are located in the vicinity of urban sites, towns and/or host settlements then the local carrying capacity may already be exceeded, placing further pressures on local natural resources and development infrastructures. Due to the combination of environmental factors, refugee hosting landscapes are some of the most challenging to engage with across the humanitarian-development nexus. Despite these complex challenges, there are still opportunities to shift the paradigm on refugee-hosting landscapes, moving from the dominant 'land degradation' assumption to the realm of 'land restoration' and 'resilience', through the implementation of gender-sensitive nature-based solutions (NbS). In the IWMI and ICRAF managed project 'circular bioeconomy solutions for resilient refugee and host communities in East Africa', the NbS have incorporated a nexus around home gardens, agroforestry and cooking energy, resulting in the development of a household circular bioeconomy model that builds food, nutrient and energy security. The regenerative activities that have been implemented at the household level include: stove construction; briquette making; charcoal making; compost production; livestock integration; greywater irrigation, home garden cultivation and tree

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Contact Address: Andrew Adam-Bradford, Oxford Brookes University, Center for Development and Emergency Practice (CENDEP), Oxford, United Kingdom, e-mail: aadam-bradford@brookes.ac.uk

planting. All these regenerative activities are not only crucial in restoring landscapes but are instrumental in building climate change adaptation capacity. In this paper, findings, constraints and lessons are presented not only from the IWMI and ICRAF managed circular bioeconomy project from four refugee camps and settlements in Kenya and Uganda, but also NbS work is presented from additional refugee hosting landscapes in Cameroon and Tanzania. The evidence-based findings from this work are applicable to other fragile environments, particularly in the context of climate change adaptation in arid and semi-arid areas.

Keywords: Adaptation, climate change, cooking energy, food, gender inclusion

Brewing a more equitable cup – game changers from producers' perspectives: Examples from Costa Rica, Tanzania, and El Salvador

ANNELIE GÜTTE

Leibniz-Centre for Agricultural Landscape Research (ZALF), e.V., Germany

Costa Rica is considered a country at the forefront of biodiversity conservation and nature protection. Yet, in 2020 87,000 tons of green coffee have been produced in the country – a crop that has been highly criticised from multiple perspectives: Its production has been linked to soil degradation and erosion, biodiversity losses, and water pollution, while common processing techniques are resource-intensive. On top of that, coffee production has been shown to be of low economic viability. Price volatility as well as climate impacts make returns from coffee produce unpredictable. Food insecurity and malnutrition have been shown to occur frequently in coffee farming households around the globe – also because of coffee farmers' precarious position in the global coffee value chain. How, then, can coffee production fit into a systemic strategy to serve sustainable development? This contribution presents results from field work activities and interviews conducted in El Salvador, Costa Rica, and Tanzania. It discusses different pathways to transform coffee systems into more equitable systems. It provides insights on what coffee farmers perceive as game changers for their coffee businesses, how this changed the way they are growing coffee and which obstacles remain. Pathways discussed include a focus on Specialty Coffee market segments, gender policy initiatives, and capacity building approaches. It is discussed how global power imbalances shape efforts and outcomes of smallholder empowerment. Results suggest that key obstacles to sustainable and equitable coffee production are not to be found at farm level but in non-transparent producer-consumer markets, impermeable value chain hierarchies biased towards importing countries as well as restrictive tariffs and trade barriers. Carrying this to the extreme, true empowerment of smallholder coffee growers might not only shift and transform current trade relations towards more equitable exchange but might have the power to disrupt the global coffee trade system depriving global players of opportunities to profit maximisation – a fact that might explain why efforts of poverty alleviation, food security and empowerment of smallholder coffee growers are either progressing slowly, stagnating or even declining.

Keywords: Capacity building, gender equity, inequity in global value chains

Contact Address: Annelie Gütte, Leibniz-Centre for Agricultural Landscape Research (ZALF), e.V., Eberswalder Straße 84, 15374 Müncheberg, Germany, e-mail: annelie_maja.guette@zalf.de

Inequity, transformation and talking hope: Towards a new discourse on climate change and sustainability

Eva-Maria McCormack, Jenny Bischofberger, Godfred Bonnah Nkansah
Talking Hope gUG, Germany

Although the climate agenda has been mainstreamed in recent years, discourses on climate have not changed much in substance: Climate action continues to be represented as a battle against impending catastrophe, although fear appeals affect change only to a limited degree. The emphasis in public, political and media debates on the costs of climate action pits intra-societal, intergenerational and international stakeholders against each other. The focus on technical solutions neglects the intersectoral and, especially, the social justice dimensions of climate impacts and solutions. The failure to communicate the intersectoral benefits of climate action also undermines the ability to pursue intersectoral solutions to intersectoral problems, with food systems inequity being one prime example. Perhaps most importantly, the failure to focus on alternative future scenarios which convey hope, self-efficacy and inclusiveness impedes public engagement for sustainability and, especially, the equal participation of disadvantaged stakeholders in the Global South and the Global North. In light of these aspects, the current discourse on sustainability is both counterproductive and inequitable: Its conceptual bias has social justice impacts which increase socio-political polarisation and marginalise disadvantaged stakeholders even further. This also hampers the wider buy-in for sustainability solutions in national and international settings. Our paper presents a new narrative on climate, which is framed along the principles of social justice and highlights the social benefits of sustainability. Drawing on psychological, sociological, communications and transformation research as well as NGO experiences, we offer a vision of sustainability, which focuses on the opportunity for a new social contract afforded by the need to address climate change. We posit the need for narratives of hopeful, alternative future scenarios to achieve sectoral and systemic change towards Net Zero, and demonstrate that the food systems transformation lends itself well to this approach as it is an immediately human-centred issue. We argue that communications approaches which derive the need for climate action from a commitment to social justice offer new potential to increase the social mandate for sustainability. Since engagement is inspired by the view of a more equitable tomorrow, this discursive shift also holds significant policy implications.

Keywords: Adaption, climate change, climate communication, social justice

Contact Address: Jenny Bischofberger, Talking Hope gUG, Research Director, Markelstr 10, 12163 Berlin, Germany, e-mail: bischofberger@talking-hope.org

Climate change and interaction with labour issues in smallholder agriculture in sub-Saharan Africa

Rodgers Mutyebere[1], Benard Maingi Mweu[2], Lydiah Ominde Nyambok[3], Koffi Kibalou Palanga[4], Ralf Schlauderer[5]

[1]*Mountains of the Moon University, Uganda*

[2]*South Eastern Kenya University, School of Agriculture, Enviroment, Water and Natural Resources, Kenya*

[3]*Jaramogi Oginga Odinga University of Science and Technology, School of Agricultural and Food Sciences, Kenya*

[4]*Kara University, Togo*

[5]*Weihenstephan-Triesdorf University of Applied Sciences, Fac. of Agriculture, Food, and Nutrition, Germany*

Farm households in sub-Saharan Africa (SSA) are increasingly affected by climate change. While a lot of international research is concentrating on effect on yield levels, the impact by reduced labour availability is less researched. The paper highlights the aspect of changing labour availability and decreasing stability of farm households in SSA. The research is done by a network of 5 partner universities in Uganda, Kenya, Togo and Germany starting in 2022. In a first step a comprehensive literature research was done. In a further step quantitative research will be established in 2023 in the areas of the PUs. Most SSA countries incl. Kenya, Uganda and Togo are already experiencing episodes of climate change of varying severity and duration. Climate variability impacts on food security, labour productivity, employment, and labour mobility. Labour migration results in farm labour scarcity through its effects on the viability of economic activities such as farming and livestock development, destruction of road infrastructures through floods and disruption of ecosystem functions. 75 % of smallholder farms in Kenya depended on household labour and also experience periodic labour fluctuation. The reduced supply of labour increases exposure to climate-related risks. The loss of farm labour due to migration cannot be balanced by hired labour. The most direct and wide-spread impacts of climate change on the labour sector is expected through heat-stress. It has reduced performance during working hours, excessive body temperature and dehydration has led to increased accidental injuries. According to a Climate Vulnerable Forum report (2016), approximately 5 % of hours worked will be lost in 2030 especially in West Africa. Another direct impact of climate variability are the incidences of malaria and other vector-and water-borne diseases which in turn affects labour productivity in SSA. In the next steps the involved PUs will collect data for better measuring and understanding the problem and to develop strategies to cope with reduced labour availability.

Keywords: Climate change, labour availability, university research network

Factors influencing youth in family farming: A study from southern India

Mohanamani Palanisamy[1], Thanammal Ravichandran[2],
Poongodi Bhupathy[1]

[1]*Kumaraguru College of Technology, KCT Business School, India*
[2]*Kumaraguru Institute of Agriculture, India*

By 2050, the world's population is projected to reach 9 billion, with youth (aged 15 to 24) making up roughly 14 % of this total. In India, 68 % (0.90 billion) of the population live in rural areas and 28 % (0.35 billion) of the population is under the age of 24. According to World Bank research, by 2050, half of the Indian population would live in cities and the proportion of employment in farming is predicted to decrease from 58.2 % in 2001 to 25.7 % by 2050. On the one hand, agriculture is a crucial activity to fulfil the rising food demand, while labour is in short supply. On the other hand, the youth unemployment rate is rising. The fact that young people today are losing interest and confidence in agriculture and allied activities is alarming. Two fundamental challenges arise due to a lack of effort by policymakers and development actors, including failure to map the competency profile of today's youth, engage them in discussions and consider their desires and aspirations both of which have led to negative opinions of agriculture as a profession. This study is aimed to explore the factors which influence youth in family farming. The study followed a qualitative research method using a grounded theory approach, as there was a dearth of information about the involvement of youth in family farming. This study has defined youth within the age group of 15 to 30 years due to their involvement in agriculture after their education, especially in India. The data were collected from 60 farming families in Coimbatore and Erode districts of Southern India, divided into two groups based on youth involvement in their family farming or not. Data collection was done on five dimensions including psychological, socio–cultural, technological, infrastructural, and economic contexts. The findings indicated that the aspirations of youth in family farming vary depending on socio–economic factors, environmental motivation, and innovative attitudes. The study compiled the challenges and constraints faced by youth in family farming, which include lack of access to technologies, financial resources, and social stigma.

Keywords: Agriculture, family farming, grounded theory, qualitative, youth

Contact Address: Mohanamani Palanisamy, Kumaraguru College of Technology, KCT Business School, 16/143-1 m.v.nagar kamaraj road, 641104 Coimbatore, India, e-mail: mohanamani@kctbs.ac.in

Is associativity the key? Unraveling power dynamics in rural trading using an 'intertwining approach'

Marco De la Cruz Sanchez[1], Diana Santos[2], Joost Dessein[1]

[1]*Ghent University, Dept. of Agricultural Economics, Belgium*
[2]*ECLOSIO, Peru*

In recent years, global efforts are increasingly trying to promote more farmer-to-farmer relationships on their road to transform imbalances in commercial exchanges and bring more bargaining power to defend against unfair dealing. This process however supposes that farmers have appropriate conditions to work and trade in organised ways, i.e., in organisations, so that to allow efficient and fairer food trade and an efficient supply chain in the long run. This is often reflected in development initiatives, which tend to favour 'organised' mechanisms of associativity (e.g., committees among farmers, etc.). We hypothesise that part of the limited reflection relates to the difficulty to explore the hidden power play mechanisms and organisational dynamics happening between farmers. We reason that associativity in rural trading necessarily involves institutional change and this can bring latent power structure to the fore that are better reflected in the 'intertwining approach'. In this sense, our study aims to understand the power dynamics and structures of the rural organisations that engage in the commercialisation of agroecological products in Aija Province, Ancash region, Peru. These organisations participated in the project Food Systems, Markets and Water (SAMA) of ECLOSIO and its partners. The organisations have operated sharing information, generating new commerce ideas, and developing capacities to realise them. Yet, reports suggest that they face challenges concerning organisational development issues and fragile interactions. Through the lenses of the 'intertwining approach', the research will reconstruct the institutional evolution of the rural organisations built under the initiatives of ECLOSIO. It will also apply a novel analytical model to provide a scheme for framing and understanding the elements that have a dominant role in structuring the organisational dynamics of commercialisation in Andean regions. Our case study demonstrates that the local dynamics influenced organisational developments and that their evolution exposed more complex mechanisms of power-play in farmers' interactions. We identify two power-play mechanisms that influenced farmers' interactions in commercial practices: 'manageability of the risks' to aligning their economic and social interests with those of the programs, and 'learning by exposition', as a means to interpret economic transactions.

Keywords: Critical institutionalism, intertwining approach, Peru, power dynamics, rural commerce, rural trading

Contact Address: Marco De la Cruz Sanchez, Ghent University, Dept. of Agricultural Economics, 3000 Leuven, Belgium, e-mail: m.delacruzs@pucp.pe

Social learning

Social learning and knowledge systems: understanding and integrating multiple actor perspectives to foster food systems transformation

Local perspectives on nonmaterial values of nature, biodiversity in rural communities in the Peruvian Amazon

GREMARY AZA[1], OLIVER FRÖR[2], JAN BÖRNER[3]

[1]*University of Passau, Bioeconomy Economics, Germany*
[2]*University of Kaiserslautern-Landau (RPTU), iES Landau, Inst. for Environmental Sciences, Germany*
[3]*University of Bonn, Center for Development Research (ZEF), Inst. for Food and Resource Economics (ILR), Germany*

Natural ecosystems provide a wide range of material and non-material benefits to human society. Despite the diversity of benefits, material benefits have been prioritised in research and policy-making. The management of ecosystems has been guided by political and economic decisions that directed attention toward the instrumental values of nature. In highly biodiverse ecosystems such as the Amazon Forest, there is little information about nonmaterial benefits and cultural ecosystem services perceived by local communities. There is a debate about whether biodiversity or forest cover is related to the perception of non-material benefits. Quantitative analyses were drawn from a dataset of 244 households living in different tropical rainforest cover levels in Amazonian Peru. Linear model regressions were computed for non-material benefits such as aesthetic, social relationships, recreational, identity, historical, kinship, and spiritual benefits. The results suggest that higher levels of forest cover are not necessarily related to the perception of non-material benefits. No differences were found by comparing perceptions of non-material benefits among three areas with different forest cover levels. Furthermore, higher values attributed to non-material benefits were explained by higher levels of forest cover only for recreation and historical benefits. It is demonstrated that other landscape characteristics such as the presence of forests and land area; socio-demographic and information factors are related to the perception and values attributed. The association of factors with perceptions and values differs among non-material benefits categories. The results of this study provide a guide about how local communities perceive the ecosystem and what non-material benefits they consider important to their lives. In the context of Madre de Dios, where forest ecosystems are threatened by high deforestation rates and migration patterns, the loss of cultural values related to nature should be addressed and incorporated into ecosystem management policies.

Keywords: Cultural ecosystem services, ecological economics, ecosystem services

Contact Address: Gremary Aza, University of Passau, Bioeconomy Economics, Dr.-Hans-Kapfinger-Str. 30, Raumnummer 242, HK30, 94032 Passau, Germany, e-mail: gremary.azamengoa@uni-passau.de

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Realities of sustainability: Application of photovoice to identify locally and culturally relevant sustainability criteria of cocoa farmers in Ecuador

Moritz Egger, Michael Curran

FiBL - Research Institute of Organic Agriculture, Austria

Sustainability concepts are contested and inherently normatively charged. Given the high levels of complexity and uncertainty in sustainability studies, it is necessary to transition towards a transdisciplinary approach to collaboratively generate knowledge that is suitable for specific local and cultural circumstances. This study aims to explore the perspectives of cocoa farmers in the coastal and Amazonian regions of Ecuador on their definition of sustainability and the locally relevant criteria that must be met to achieve it. A total of 20 female and 23 male farmers were provided with photo cameras, and over a period of 4 weeks, they analysed the pictures taken within their group to identify the elements that contribute to sustainability in their lives as cocoa producers. The visual medium of photographs proved to be an effective way to overcome social and language barriers, as participants were motivated by the group setting to share and discuss the realities presented in the images, whether they depicted their own experiences or those of their peers. In both study regions, lists of approximately 40 sustainability criteria that are locally relevant were compiled. The importance, development, and influential actors for each criterion were documented, and the images were categorised according to the sustainability criteria they represented. The results indicate that the environment in which farmers operate greatly shapes their views on what is necessary for sustainable livelihoods. Thus, local perspectives should be considered when developing strategies to enhance sustainability. The key strength of this study was that the participants were responsible for selecting the topics of interest through their photographs and discussions, while the researchers merely facilitated the process.

Keywords: Cocoa, Ecuador, photovoice, sustainability, transdisciplinarity

Contact Address: Moritz Egger, FiBL - Research Institute of Organic Agriculture, Kleistgasse 3, 1030 Vienna, Austria, e-mail: moritz.egger@fibl.org

The importance of "collectivity" for transformative pastoral food systems

Fiona Flintan, Kelvin Shikuku

International Livestock Research Insitute, Italy

More than ever before pastoral food systems of East Africa face pressures to transform into more organised and productive food systems, contributing more directly to national economies and national development plans. This is whilst trying to deal with ongoing and new challenges including land tenure insecurity, lack of rural infrastructure, services and markets, multiplying invasive species and climate change. An important characteristic of well-functioning pastoral systems is "collectivity." That is, being well-connected to the other members of the pastoral group, both socially and geographically allowing sharing of resources and reciprocal exchanges that provide for spreading risk across the group rather than that risk falling on the shoulders of individuals. Empirical evidence from a recent survey of 1,983 households in Ethiopia showed that households that received but also redistributed food aid through their social network had a greater ability to cope with drought than those that did not redistribute food aid. However, most development and humanitarian interventions have focused their efforts on pastoral individuals or households, and rarely targeted the group or the collective, for example through establishing individual water storage tanks (in Ethiopia), individual livestock-based insurance contracts (in Kenya and Ethiopia) or women's individual land certificates (in Tanzania). Though these interventions may have assisted individuals in the short term, they are may have contributed to the individualism and privatisation of resources and the breakdown of the collective as well as reducing the long term "group" benefits for individual members. Development and humanitarian organisations need to rethink their interventions in pastoral areas and how they are implemented if pastoral food systems are to transform into more organised and productive food systems. This requires seeking out and developing those interventions that focus on and aim to build the strength of the collective group. At the same time the measures to redistribute wealth and support poorer and weaker members of the group need to be strengthened. Examples of such approaches can be found in joint land use planning and rangeland management approaches that seek to strengthen the group and sharing of resources, whilst ensuring all members of the group benefit.

Keywords: Collectivity, development, humanitarian, pastoralism

Contact Address: Fiona Flintan, International Livestock Research Insitute, Rome, Italy, e-mail: f.flintan@cgiar.org

Experiential learning and the power of women

THOMAS FALK[1], LARA BARTELS[2], BJÖRN VOLLAN[3], IVO STEIMANIS[3]

[1]*International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Germany*

[2]*ZEW – Leibniz Centre for European Economic Research, Germany*

[3]*University of Marburg, Sustainable Use of Natural Resources, Germany*

An emerging body of research explores the use of experiential learning games as an intervention to facilitate sustainable natural resource management. These games are structured spaces where players can acquire knowledge by experiencing, reflecting, and experimenting. Learning outcomes associated with games include improving system understanding, enhancing problem-solving capacities, changes in social norms, participatory institutional change, and strengthened collective action. While games have become a more common intervention tool, measuring impacts on individual and collective real-life behavioural change well after game sessions is still rare. We conducted games with users of a local public good – a rainfed dam for irrigation – in 56 randomly selected villages in Madhya Pradesh, India. Additional 27 villages were randomly drawn as control sites. These communities depend on rainfed dams for complementary irrigation. Nonetheless, many dams in the study area are maintained poorly and water usage is hardly coordinated undermining the effectiveness of the irrigation system. While there are good examples of successful long-term interventions to support communities, these are often very time and facilitation intensive and consequently implemented with limited reach. We explore the potential of games as a scalable, low-cost intervention to facilitate behavioural changes in sustainable water management. We find a lasting direct treatment effect on actual dam maintenance while there is no effect on the existence of dam management rules. In addition, we find that the larger the share of women in the sessions, the more likely is maintenance taking place at a site two years after the intervention. Our study increased the confidence that games can play a critical role in designing natural resource management interventions on a large scale. If kept simple, their clear structure can be easily learned by civil society and government field workers. The low intervention costs and favourable return on investment should be motivation to integrate such intervention in resource related programs. The games can complement widespread more technical interventions by supporting participatory behavioural change processes. Until December 2022, implementing partners have applied the specific game tool in more than 1700 communities across different states of India.

Keywords: Games, India, social dilemma, social learning, water management

Contact Address: Thomas Falk, International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Heinrich-Mann-Str. 20, 79100 Freiburg, Germany, e-mail: t.falk@cgiar.org

The human dimensions of climate-related security risks in rural settings: A social learning approach

Leonardo Medina Santa Cruz[1], Michelle Chevelev-Bonatti[1],
Ignacio Madurga López[2]

[1]*Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Germany*
[2]*The Alliance of Bioversity International and CIAT, Brazil*

The linkages between climate change, human security and conflict have been the subject of considerable debate over the past decade. Main critical voices on the climate security field frequently focus on the limits of structural approaches to understanding causal pathways between climate and conflict, sampling biases during data collection, a minimal focus on micro-level insecurity, and the disregard of power relations in bringing about structural sources of insecurity and vulnerability. The combination of these research gaps has led to decontextualized constructions of system dynamics, which often ignore local cultural realities and lived experiences of affected populations. As a result, there is a limited understanding of what effective policy and programmatic practices that address climate-related security risks entail. Strategies have so far prioritised technocratic solutions and top-down governance arrangements. This study draws from social learning theory to understand everyday experiences of agriculture-dependent communities affected by climate impacts under a diversity of security and conflict-related risks. It also intends to advise programmatic practices for conflict-sensitive climate action. The methodology is based on participatory appraisal methods to engage community voices in developing "climate security pathways" that better relate to people´s everyday experience of the compounding risks brought about by climate variability and human insecurity. Data was gathered through dialogue processes lasting four or five days across 13 locations in Kenya, Senegal, Zambia, Philippines and Guatemala, with over 300 participants distributed equally among women and men. Preliminary results suggest that climate security programming is unlikely to contribute to sustainable peacebuilding unless it conceptualises and targets the intermediary factors making up climate-insecurity feedback loops, as understood by populations affected by conflict. In this regard, interventions need to provide the space for people to define and question the institutionalised practices and values acting as either structural drivers of conflict or constraints to peace. Climate action needs to account for development models that challenge structural and intersectional sources of vulnerability, such as inequality, political exclusion, gender-based violence, and resource entitlements. Programmes also need to endorse positive ontologies of conflict as productive mechanisms for societal transformations towards justice.

Keywords: Climate security, conflict transformation, environmental peacebuilding, social learning

Contact Address: Leonardo Medina Santa Cruz, Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Müncheberg, Germany, e-mail: leonardo.medina.s@gmail.com

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Is community participation necessary for the success of development programmes? Key lessons from Pakistan

Ayat Ullah, Miroslava Bavorová, Giri Prasad Kandel

Czech University of Life Sciences, Prague, Fac. of Tropical AgriSciences, Dept. of Economics and Development, Czech Republic

Active and effective participation of local communities in the planning and implementation of projects is critical to achieving sustainable forest landscape restoration. The objective of this study was to examine the activities undertaken by the Forest Department to promote community participation in forest landscape restoration and to identify the factors that influenced household level of participation in the Billion Trees Afforestation Project (BTAP) in Pakistan. Data were collected from households through surveys and from forest department officials through in-depth interviews, while descriptive statistics and ordered logit model were used to analyse the data. The study found that households with a high level of participation in BTAP received more landscape restoration and livelihood benefits compared to communities with medium and low level of participation. The results of the ordered logit model show that households' decisions to participate in the BTAP at a higher level depend on education, awareness of BTAP participation policies and procedures, and membership in community-based organisations (CBOs), while political tensions and elite capture lead to low level participation decisions. The results of the in-depth interviews show that the important factors that prevented community members from participating at higher level in the BTAP included nepotism, irregular rainfall, lack of knowledge and skills development programs, unattractive land tenure policies, ineffective communication networks, and delays in providing salaries to community members. We recommended that the government and other stakeholders need to understand these factors that influenced households' high level of participation in afforestation projects to improve the success of landscape restoration initiatives and rural livelihoods.

Keywords: Billion trees afforestation project, forest landscape restoration, participation of local communities, projects planning and implementation

Games for social learning: Triggering collective changes in commons management

Thomas Falk[1], Wei Zhang[2], Ruth Meinzen-Dick[2], Richu Sanil[3], Pratiti Priyadarshini[3], Ilkhom Soliev[4], Lara Bartels[5]

[1]*International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Germany*

[2]*International Food Policy Research Institute (IFPRI), United States*

[3]*Foundation for Ecological Security, India*

[4]*Martin Luther University Halle-Wittenberg, Germany*

[5]*ZEW – Leibniz Centre for European Economic Research, Germany*

As resource users interact and impose externalities onto each other, institutions are needed to coordinate resource use, create trust, and provide incentives for sustainable management. Coordinated collective action can play a key role in enabling communities to manage natural resource commons more sustainably. But when such collective action is not present, what can be done to foster it? And can this be done at scale? This paper examines the potential to adapt behavioural games as a structured, replicable approach to facilitate the emergence of sustainable commons management at scale. In the past, researchers have used behavioural games to study cooperation patterns of communities. Recently, games have been adapted as learning and stakeholder engagement tools to improve management of the commons, strengthen self-regulation of resource use and enhance constructive interaction of resource users. Combining games with other interventions and tools and facilitated discussions has been proposed as a promising approach to improve collective action institutions through experiential learning. This paper aims to improve the understanding of how experiential learning through games can contribute to behavioural change, potentially leading to more sustainable commons management. We first develop a conceptual framework for structuring the reflection on games as experiential learning interventions. We then apply the framework to synthesize the lessons learned from applying three experiential learning games to trigger behavioural change in India. This should help to identify the potential and strategies for scaling up the use of games for individual and social learning in commons management. We conclude that games have potential as intervention tools for sustainable resource management, but to achieve that potential, careful attention to underlying behavioural assumptions in using games is urgently needed in research, policy, and design of interventions.

Keywords: Behavioural change, facilitation tools, forest, india, sustainable natural resource management, water

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Contact Address: Thomas Falk, International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Heinrich-Mann-Str. 20, 79100 Freiburg, Germany, e-mail: t.falk@cgiar.org

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Collaborative learning to encourage adoption of agroecology: A participatory video-based farmer-to-farmer learning process in Cambodia

Lilian Beck[1,2], Claudia Bieling[1], Delia Catacutan[2], Anna Hofny-Collins[3], Sabine Douxchamps[4]

[1]*University of Hohenheim, Societal Transition and Agriculture, Germany*
[2]*World Agroforestry Center, Cambodia*
[3]*Swedish University of Agricultural Sciences, Sweden*
[4]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Vietnam*

Despite many claims of agroecological small-scale farming systems being a future path to improve farmers' livelihoods and secure a sustainable food supply, farmers are only sometimes willing to apply these practices even though they have learned about them. While many studies investigate socio-economic barriers to adoption, only very few investigate socio-cultural barriers and those imposed by the mode of facilitating learning. This highlights the need to evaluate how extension services are typically organised and develop alternative learning approaches considering the socio-cultural context. Therefore, discouraging reasons for applying agroecological practices with a focus on agroforestry among farmers were investigated through an action research process in the North of Cambodia and in-depth interviews with small-scale farmers. By introducing an empowerment process in which comprehension is gained while respecting farmers' perceptions, this study shed light on the divergent world views and negotiation processes farmers consider when making management decisions as well as the barriers imposed by the way farmers' learning is facilitated. This study identified and contributed to three separate but related thematic fields. First, it explored the negotiation processes between different cosmological concepts when farmers decide to apply agroecological practices. Second, it investigated the evaluation by farmers regarding socio-economic, ecological, and technical feasibility and desirability of the technology. Thirdly, it studies the influence of the relationship between farmers and local extension actors in the context of co-creation of knowledge about agroecological methods. It explains thereby how these aspects are influenced by the mode in which learning is facilitated. Based on these insights, an alternative extension approach has been developed, facilitated, and evaluated to overcome the identified barriers to facilitating successful learning among farmers. The proposed alternative is a collaborative learning approach combining farmer-to-farmer teaching and participatory videography.

Keywords: Action research, adoption barriers, agricultural extension, agroecology, Cambodia, collaborative learning, farmer adoption, farmer-to-farmer, innovations, participatory video, transdisciplinary research

Contact Address: Lilian Beck, University of Hohenheim, Societal Transition and Agriculture, Schloss Museumsflügel, 70599 Stuttgart, Germany, e-mail: libk@posteo.de

Collective action and social learning in integrated resource systems: Evidence from inland fisheries in Cambodia

Pia Gleich[1], Carla Baldivieso[1], Sanjiv De Silva[2],
Michelle Chevelev-Bonatti[3]

[1]*Humboldt Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*
[2]*International Water Management Institute, Sri Lanka*
[3]*Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Germany*

In rural Cambodia, inland freshwater and rice field fisheries are key sources of income, animal protein, and other important ecosystem services in the area. Community Fish Refuges (CFRs) which are conservation areas in community-owned fish ponds, seem to be a promising path to not only sustain fish stocks, aquatic biodiversity and secure water for agriculture and husbandry but to simultaneously strengthen collective management. However, not all processes that are successful in ecological terms perform equally well in social terms. To explore how CFRs can promote social and ecological change, we investigated two CFRs that were established in 2016 by local and international NGOs, as well as authorities of the Kampong Thom Province. Our aim is to identify the extent to which those CFR projects support the formation of collective management and facilitate social learning processes. To do so, a qualitative case study was conducted from March to May 2023 in two CFR locations in the Kampong Thom Province of Cambodia. The cases show similar ecological features but show different results in management terms according to the local implementing NGO. Semi-structured interviews (n=103) were conducted with different local actors connected to the resource. Noting that CFR management is vested in a few elite actors with very limited active participation and agency of other resource users, we conclude that possibilities for collective action and social learning are limited. Power centralisation, surveillance and remains of historical patron-client relationships contribute to configurations in which village and resource management are marked by strong vertical structures of authority.

Keywords: Cambodia, collective action, qualitative research, social learning

Contact Address: Pia Gleich, Humboldt Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Berlin, Germany, e-mail: gleichpi@hu-berlin.de

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Mapping knowledge for managing aquatic food systems: The case of community fish refuges in Cambodia

Carla Baldivieso[1], Michelle Chevelev-Bonatti[2], Sanjiv Da Silva[3], Dubois Mark[3], Stefan Sieber[2,1]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*
[2]*Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Germany*
[3]*International Water Management Institute, Laos*

Mapping complex knowledge systems allows us to support initiatives that contribute to collective action around sustainable food systems. In Cambodia, aquatic food systems are embedded in the rice paddy landscape; thus, rice-field fisheries play a significant role. Community Fish Refuges (CFRs), are natural or human-made ponds that hold water throughout the year and provide a dry season sanctuary for fish. However, CFRs are not only contributing to the maintenance of fish stocks but are an integrated agricultural system that provides water for animals and household consumption and supports aquatic biodiversity. For our research, we selected four cases from the CFR project conducted by WorldFish - Cambodia in the period 2016 – 2021 in the Kampong Thom Province. These cases were identified by the local NGO team as successful project implementers. We applied causal loop diagrams (CLD) as a participatory tool through focus groups discussion with representatives of rural villages. Our aim was to make explicit the knowledge systems and processes related to this particular aquatic food system, deriving insights about its role in the CFRs management. The methodological approach is based on three phases: a) exploratory studies, b) casual loops workshops b) workshops of data validation, conducted between June-December, 2022. We identified the effectiveness of CLDs for visualizing knowledge systems and resource management. We observed that the participants have a bricoloured knowledge, rooted on generationally transmitted traditions but greatly influenced by external actors. We visualized that their knowledge systems are based on the daily practice of the use of CFRs and formal processes of training. However, such formal knowledge is linked to local groups with greater access to power ties and; therefore, larger facilities to be part of rural extension processes. In turn, the knowledge exchange processes with other villagers are seen from an informative and top-down approach. These local power groups execute appropriate actions for the ecological sustainability of

Contact Address: Carla Baldivieso, Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Oranienstrasse 116, 10969 Berlin, Germany, e-mail: carla.baldivieso.s@gmail.com

the project. However, CFRs could benefit from processes in which there is a dialogue with a greater plurality of voices. These dialogical processes within the village do not appear to be locally available; this, could be linked to existing social differentiation structures and cultures of power. Therefore, our discussion ties together local learning, power structures and cultures, and the role of externals.

Keywords: Aquatic food systems, Cambodia, causal loop diagrams

Spatially explicit representation of climate-smart agriculture in Ghana: A participatory scenario process

Roman Hinz[1], Rüdiger Schaldach[1], Reginald Tang Guuroh[2], Eveline Sawadogo-Compaore[3], Stephen Adu-Bredu[2]

[1]*University of Kassel, Kassel Institute for Sustainability, Center for Environmental Systems Research (CESR), Germany*

[2]*Council for Scientific and Industrial Research (CSIR), Forestry Research Institute of Ghana (FORIG), Ghana*

[3]*Inst. for Environment and Agricultural Research (INERA), Natural Resource Management and Production Systems, Burkina Faso*

Africa is the continent with the lowest total and per capita greenhouse gas (GHG) emissions. Nevertheless, to meet global emission reduction targets, scenarios indicate that mitigation measures will be needed also in low- and middle-income countries. In Ghana, agriculture is one of the main drivers of land-use change and contributes to the emission of greenhouse gases. Against this backdrop, climate-smart agriculture (CSA) and forestry (CSF) is widely promoted as an approach to reorient rural development under conditions of global change. The concept incorporates climate change mitigation practices in the agriculture, forestry and other land use sectors (AFOLU) that address the need to achieve food security and other development goals (e.g., enhanced resilience), but in a way that also minimises GHG emissions. Operationalisation of these promising measures is still lacking and potential synergies and trade-offs are often not considered in current national-scale assessments. Therefore, decision support tools are needed to help in understanding the status quo, as well as to prioritise and thus implement appropriate mitigation options. In this contribution, we present the method and first results of the participatory scenario development process that we conduct as part of the BMBF-funded project GreenGaDe in Ghana. Our objectives are (1) to analyse the feasibility and societal acceptance of various low-emission agriculture and forestry practices, as well as (2) to identify their potential locations and spatial extent at the national level. Scenario assumptions are based on the results from a participatory stakeholder process (interviews and local workshops) in combination with desktop analyses. In the first step, we develop storylines (qualitative scenarios) that integrate stakeholder knowledge about CSA and CSF with global boundary conditions derived from the shared socioeconomic pathways (SSPs). In the second step, we translate these qualitative scenarios into quantitative scenarios (e.g., GIS maps and emission inventories) using

Contact Address: Roman Hinz, University of Kassel, Kassel Institute for Sustainability, Center for Environmental Systems Research (CESR), Wilhelmshöher Allee 47, 34117 Kassel, Germany, e-mail: roman.hinz@uni-kassel.de

spatial simulation models for calculating land-use changes and environmental impacts (e.g., agricultural expansion, GHG emissions). Our results may help to identify feasible climate mitigation potentials in the AFOLU sector in Ghana as a prerequisite to define national climate policies and to accelerate adequate economic investments to support CSA and CSF measures.

Using video technology as an agricultural extension tool: A case study on climate smart agriculture in Uganda

JAMES BILLY KASULE, CHRISTINE BOSCH

University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Videos can be used successfully in agricultural extension, particularly in reaching marginalised, resource-poor farmers mobilised in groups, particularly women, youth, and those with little prior knowledge of new practices and technologies. While there is a renewed interest in videos, there is a knowledge gap concerning farmers' perception of such videos, especially of female farmers. The study aimed to understand how farmers in Uganda perceive video technology as an agricultural extension tool for Climate Smart Agriculture (CSA) practices and assess the extension agents' perception of using videos in extension services. The qualitative data collected resulted from the BMZ-funded project Reaching Smallholder Women Farmers with Information Services and Resilience Strategies to Respond to Climate Change'in four districts in the Central Region of Uganda. The study comprised 1443 female and 770 male smallholder farmers who watched videos demonstrating soil and water management, integrated pest management, poultry and piggery management CSA practices, and 49 extension agents who were trained on the project's concept. From this study population, 111 female and 70 male smallholder farmers who watched videos demonstrating Climate Smart Agriculture (CSA) practices were chosen randomly to participate in the FGDs, and 6 extension agents were interviewed using semi-structured questionnaires. The study findings revealed that smallholder women farmers found it motivating and easy to learn about CSA practices through videos and related discussions with extension agents. Extension agents perceived that CSA video technology could complement other existing extension approaches. On the other hand, the main challenges included unwillingness to invest in short agricultural videos, inadequate video infrastructure in rural areas, and technical know-how on using videos among farmers and extension agents. To complement extension services, the study recommends investing more in creating and disseminating agricultural videos by the relevant stakeholders in Uganda's agricultural sector. Additional investments could include enhancing the quality of agricultural video production and messages, constructing video infrastructure in rural sub-counties, and enhancing the capacity of extension agents who use agricultural video technologies.

Keywords: Agricultural extension, climate-smart agriculture practices, female farmers, Uganda, videos

Contact Address: James Billy Kasule, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 13, 70599 Stuttgart, Germany, e-mail: james.billk93@gmail.com

Empowering smallholder farmers in climate field schools: Farmer led-research

Lena Winter[1], Daniel Lesmana[2], Narimeh Paeplow[1], Tandu Ramba[3], Kustiwa Adinata[4], Silke Stöber[1]

[1]*Humboldt-Universität zu Berlin, Centre for Rural Development, Germany*
[2]*Hasanuddin University, Indonesia*
[3]*Motivator Kondoran, Adaptation and Mitigation of Climate Change, Indonesia*
[4]*Jamtani, Indonesia*

Farmers are local experts of their socio-ecological systems. With their knowledge and skills on land, plant and local weather, farmers are responsible actors in the food system at local and global scale. Climatic changes caused by global warming happen so rapidly that they outrun farmers´ ability to adapt to them. Tropical Indonesia, with its thousands of islands is not only vulnerable to sea level rise, but also faces rising temperatures, unpredictable and erratic rainfall patterns leading to extreme events, floods, droughts, strong winds and landslides. The risk perception paradox that illustrates the gap between perception of the impacts of climate change and the capacity to act or adapt, can be moderated by farmer-led adaptation research. Ten years ago, Climate Field Schools (CFS) were established in Indonesia allowing a space for bottom-up learning between farmers and scientists on agrometeorological learning and climate-resilient practices. In the "school without borders" everyone is regarded as a co-researcher and knowledge is co-created.

The aim of the study is to document the impact of CFS to transforming local food systems from the perspective of local smallholder farmers in Pangandaran, West Java and Tana Toraja, South Sulawesi. Farmers of the two food regions were engaged in a participatory action research that employs filmmaking and photography with subsequent semi-structured interviews with groups and individuals. The extent to which changes in rice and chili cultivation practices and increased awareness of climate change lead to changes in collaborative and social systems was investigated. How far CFS influenced farmers´ adaptive capacities was another analysed aspect. The visuals and associated stories form a basis for reaching out to decision- and policy-makers. The study illustrates what impacts on local food systems emerge from the analysis of the collected materials. One of the findings is that farmers perceive CFS as an empowerment process since they have increased their problem-solving skills and experienced symmetric communication at eye level with other actors.

Keywords: Adaptation, climate field schools, co-research, Indonesia, participatory research

Discovering Sri Lankan expert mangrove stakeholder views and attitudes toward mangrove management using Q methodology

Thanne Walawwe Gedera Fathima Mafaziya Nijamdeen[1], Hajaniaina A. Ratsimbazafy[2,1], Kodikara Arachchilage Sunanda Kodikara[3], Ashara Nijamdeen[4], Thahira Thajudeen[5], Sofia Peruzzo[1], Maheshwaran Govender[1], Farid Dahdouh-Guebas[1], Jean Hugé[6,1]

[1]*Université Libre de Bruxelles - ULB, Dept. of Organism Biology, Systems Ecology and Resource Management Research Unit (SERM), Belgium*

[2]*Université de Tuléar, Inst. Halieutiques et des Sciences Marines, Madagascar*

[3]*University of Ruhuna, Fac. of Science, Dept. of Botany, Sri Lanka*

[4]*University of Bonn, Fac. of Agriculture, Germany*

[5]*COMSATS University, Dept. of Biosciences, Pakistan*

[6]*Open University of the Netherlands, Dept. of Environmental Sciences, The Netherlands*

Effective decision-making is essential for successful conservation and management of natural resources, including mangrove ecosystems, which offer a variety of goods and services and are managed by different stakeholders. However, mangrove conservation and management in Sri Lanka face unique challenges due to their location in the land-sea interface and the rapid coastal development observed in the Global South. Unfortunately, mangroves in Sri Lanka are currently degrading due to a combination of natural and human-induced factors, further exacerbated by the economic crisis resulting from the COVID-19 pandemic. Despite formal government regulations that prohibit access to these areas, coastal communities in Sri Lanka still heavily rely on mangrove goods and services for their livelihoods. To promote effective decision-making and facilitate mangrove conservation in Sri Lanka, this study aimed to explore the viewpoints of mangrove management experts. The study employed Q methodology and involved 71 mangrove experts from 21 stakeholder groups, who were asked to rank statements on mangrove management. The experts' rankings were subsequently analysed and clustered, leading to the identification of three discourses on mangrove management: community-oriented management, government-oriented management, and management in synergy between the government and communities. Based on the findings, the study recommends co-management of mangroves by the government and local communities to ensure environmental sustainability not just in Sri Lanka but also beyond. The study highlights the importance of participatory management, social-ecological systems, environmental governance, Q methodology, and coastal management in mangrove conserva-

tion and management. By gaining insights into the different viewpoints of mangrove management experts, the study provides baseline data for effective decision-making and serves as a valuable resource for policymakers, stakeholders, and researchers interested in promoting mangrove conservation and management.

Keywords: Coastal administration, ecological systems, environmental administration, participative governance, Q- methodology, society interdependence

The underlying causes of deforestation during "peacetime": Evidence from the implementation of the peace agreement in Colombia

Natalia Triana-Angel[1], Ana Milagros Pirela Ríos[2], John Jairo Junca Paredes[1], Stefan Burkart[1]

[1]*The Alliance of Bioversity International and CIAT, Trop. Forages Program, Colombia*
[2]*Universidad EAFIT, School of Finance, Economics and Government, Colombia*

The acceleration of deforestation is one of the unexpected consequences of the signing of the Peace Agreement between the Colombian government and the FARC-EP guerrilla in 2016. In recent years, deforested areas have increased in territories previously occupied by guerrilla and paramilitary groups, while illicit crops have expanded, and the violence perpetrated by other illegal armed groups has intensified. This research seeks to understand the relationship between the implementation of the Peace Agreement and deforestation in Colombia, mainly through a quantitative approach. Satellite data on tree cover, land cover, and coca cultivation, were combined with data on violence rates to understand the factors behind increasing deforestation in territories affected by conflict. These results were put in relation with the Final Report of the Colombian Truth Commission, which further elaborates on the reasons why peace and stabilisation remain elusive in Colombia, even after FARC-EP demobilisation. Impoverished territories historically neglected by the Colombian state, nuclei of confrontation and instability, are still suffering the ambivalences of war and the struggle over natural resources, mostly due the delays in the implementation of the Agreement. We found a positive relationship between the presence of illegal armed actors, coca cultivation, and deforestation in the areas most strongly affected by conflict, all during the implementation stage of the Peace Agreement between 2016 and 2019. The results indicate that, for these municipalities, armed conflict did not end in 2016, but rather transformed into a violent, tangible struggle with other protagonists, challenges, and disputes over land tenure and land use.

Keywords: Conflict, deforestation, illicit crops, insurgency, peace building, violence

Game farming as sustainable livelihoods and biodiversity conservation strategy in Okavango rural communities in Botswana

Oluwatoyin Kolawole

University of Botswana, Okavango Research Institute, Botswana

The push for environmental stewardship and justice continues to find relevance in debates on the relevance and importance of local-level participation in natural resource governance. Rural communities situated within wildlife management areas (WMAs) could play vital roles in enhancing sustainable environmental conservation if utmost consideration is given to their indigenous ecological knowledge and livelihoods within the context of a holistic natural resource conservation. This paper addresses game farming as a strategy for achieving both sustainable livelihoods for local communities and environmental conservation. Rooted in the Ostrom's socio-ecological framework, the analysis focuses on the need to create opportunities for local farmers to diversify their livelihoods from core farming to a combination of both farming and game rearing within the context of climate change in an arid environment where mainstream farming may prove daunting due to the prevalent harsh climatic conditions that often jeopardise traditional, peasant agriculture. Understandably, the reactionary attitudes of indigent local communities to centralised conservation approaches continues to lead to massive failure in conservation objectives in developing economies. The urge to minimise human wildlife conflicts and enhance local people's sense of place and ownership of resources, therefore, are veritable avenues for enhancing individuals' drive towards environmental stewardship and sustainable rural entrepreneurship development. The recent introduction of certain guidelines by the Botswana's Department of Wildlife and National Parks (DWNP) on how to help small farmers acquire ownership of game and manage them on their farms is, therefore, a step forward in achieving biodiversity conservation goals. The paper thus employs critical analyses to provide a road map for driving natural resource conservation and sustainable rural livelihoods in the Okavango Delta, Botswana.

Keywords: Botswana, entrepreneurship development, environmental stewardship, game farming, natural resource conservation, Okavango Delta, rural communities, small farmers

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Contact Address: Oluwatoyin Kolawole, University of Botswana, Okavango Research Institute, Shorobe road, Maun, Botswana, e-mail: tkolawole@ub.ac.bw

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Using photovoice as an M&E tool: Evidence of change from smallholder livestock producers' perspective in Vietnam

Tu Mai[1], Mary Atieno[2]

[1]*International Livestock Research Center (ILRI), Vietnam*
[2]*International Center for Tropical Agriculture (CIAT), Trop. Forages Program, Vietnam*

Photovoice, or storytelling through photos, is a participatory method which uses photography to enhance dialogues and discussions. Community members are given cameras to take photos of concerned topics. Under the CGIAR research program on livestock in Vietnam – "Livestock-led interventions towards equitable livelihoods and improved environment in the North-West Highlands of Vietnam (*Li-chăn*)", photovoice was used as a community-based monitoring and evaluation (M&E) tool with Thai and Hmong farmers, in Son La province, Vietnam. In Li-chan's photovoice study, 20 user-friendly cameras were given to 18 farmers and 2 commune veterinarians, to document livestock-related issues, identify how they traditionally raise livestock and evidence of change from project interventions around animal genetics, animal health & biosecurity, feeds and forages, environmental impacts, improved market linkages and collective action. The photovoice results gave insights on the effectiveness of promoted interventions, bottlenecks and opportunities to accelerate scaling. The study outputs showed evidence that farmers and veterinarians improved their knowledge on animal husbandry, including breeding, artificial insemination, biosecurity, farm management, improved forages, animal nutrition, feed preservation, erosion control, biomass recycling and benefits of collective action. Livestock-led innovations were adopted by farmers and reached policy makers at different levels. Photovoice was proved to be a suitable participatory method with the ethnic minority communities in Vietnam as it helped to overcome language barriers and stimulated active discussions amongst farmers. When working with ethnic minorities, photovoice methodology enables researchers and community members to become co-researchers and co-learners through equitably sharing of knowledge and experiences. In M&E of an integrated livestock development project, it can help to provide evidence of best-fit interventions in forms of photo and stories. It also helps to trigger wider adoption among community farmers and even further through reaching and influencing programme and policy makers.

Contact Address: Tu Mai, International Livestock Research Center (ILRI), Hanoi, Vietnam, e-mail: maihaian@gmail.com

Sustainable use and conservation of wild food plants through indigenous wisdom

Nishanth Gurav[1], Mohamed Abdul Kareem[2], Zbynek Polesny[1]

[1]*Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Czech Republic*
[2]*The University of Trans-Disciplinary Health Sciences and Technology, Centre for Conservation of Natural Resources (CCNR), India*

Globally, biodiversity loss is one of the most pressing environmental issues. Tribal communities in the Bastar region of Chhattisgarh, India, such as the Gond are known to be well-versed in their local biodiversity and practice sustainable harvesting. This knowledge however is disappearing at a rapid pace due to urbanisation. This study aims at documenting traditional plant use management that can be used in local conservation strategies. A mixed-methods approach was applied involving visits to randomly selected villages and conducting focus group discussions to understand the perspective of the community. Followed by this, semi-structured interviews of 50 randomly selected (25 men and 25 women) locals were conducted.

The preliminary results show that the locals use 100 wild edible plants which include leafy vegetables, tubers, fruits, and flowers. As part of the ethnobotanical documentation data recorded included local names and uses, parts used, and harvesting techniques. The results show that local communities apply species-specific sustainable harvesting practices and various methods of preparation of tuberous plants (17 species) and that the medicinal-food relation in plant use is a common aspect. The study also found that local communities preserved certain forest patches called sacred groves leaving them undisturbed for hundreds of years. Identification and botanical documentation of 50 sacred groves showed that the community-managed sacred groves had strict prohibitions on the use of plants especially trees inside the sacred groves. The results from the interviews and observation show there is a clear presence of biodiversity conservation practices with 80 % of the respondents agreeing to practice sustainable harvesting practices.

Keywords: Ethnobotany, sacred forests, sacred groves, sustainable harvesting, wild edible plants

Contact Address: Nishanth Gurav, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Kamycka 129, 16500 Prague, Czech Republic, e-mail: gurav@ftz.czu.cz

Highlighting project impact: The underestimated power of personal stories

Eva Goldmann, Akanksha Singh

Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

Measuring the impact of project interventions becomes a more and more common request from donor organisations. In the quest for measurable impact and the aim to assess project interventions, the scientific community commonly uses surveys. Indeed, well-planned surveys and interviews are crucial for quantifiable tools such as impact evaluation, which aims to establish a causal relationship between the project intervention and its impact on people's lives. However, these tools are highly demanding in costs and scientific conceptualisation, usually exceeding the project's scope. Often a false compromise is made, leading to extensive survey data, which lacks comparability across surveyed groups, causal connection with interventions, or baseline data. When such anonymous quantitative data lacks rigid scientific validation it tells us very little about the lives of the interviewed people. Conclusions from such data make it hard for us to understand the realities of people involved in the project and how the track of their lives might have changed through exposure to project interventions. We have tried out a diametrically different approach within the system comparison trial in the tropics (SysCom) in India. The project works with farmers and a team of national and international researchers on organic cotton. For the series "Faces of Organic Cotton", we have talked to eleven people involved at some level within the project, including farmers, researchers, cotton processors, and school children. The conversations followed general questions and were guided by curiosity to understand more of the interviewee's life beyond the project. The result was 11 highly personal stories, where the project and its effect are only one facets of people's lives. We have considered the inherent challenges of such an approach: translation, bias to over-positivity, and white saviorism. The stories were written in first person, attempting to represent their own stories in their own words as accurately as possible. The text was complemented by high-quality photographs and published on social media, websites, and a booklet. The reactions and feedback were very positive, allowing donors, companies, and consumers alike to understand better the impact of organic cotton in the region where it's grown.

Keywords: Cotton, impact, India, organic, participatory research, story telling

Production of training materials – "research guides"- for international agricultural research, training and communication

Rainer Zachmann

Ex-CGIAR (CIP, IITA), Germany

The "Father of the Green Revolution", Norman Borlaug, once expressed that the Green Revolution would not have been possible without training. A training study, commissioned by the Science Council of the CGIAR, and concluded in 2006, confirmed that "Training is regarded as an indispensable element of Centers' research, ..." with the aim of strengthening the institutional capacity of national agricultural research systems (NARS) to undertake collaborative scientific research. Through experience at the International Potato Center (CIP), Lima, Perú, the need for training materials became evident. Thus, CIP's training program guided scientists through the production of 25 technical information bulletins (TIBs) in English and Spanish. An introductory statement explains: "CIP's technical information bulletins (TIBs) contain information for potato production, training and research. Although directed at an intermediate professional level, the information can be adapted for communication with farmers." To encourage adaptation, CIP placed emphasis on simple language and presentation, while maintaining scientific precision. Therefore, the instructional design considered specific criteria with respect to structure, format, writing and editing. Each TIB included an evaluation sheet, addressed to CIP, for continued adjustment in content and presentation. In effect, the TIBs were used in newspaper advice for farmers, and - partially - translated into French, Arabic, Bengali, Chinese, Farsi, Greek, Hindi, Urdu ... as far as it became known. Additionally, CIP authorised the Editorial Agropecuaria Hemisferio Sur, Uruguay, to reproduce and commercialise the TIBs in South America, Mexico and Spain. With the experience from CIP, the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, initiated the production of - eventually 70 - now named "IITA Research Guides (IRGs)" in English and French. Subjects include crop production, social sciences, plant pathology, entomology, (research) farm management,... Further translations and adaptations have not been known so far, however training and workshops resulted in the production of similar training materials by NARS institutions in Ghana, Côte d'Ivoire and Zambia.

Keywords: CGIAR, training, training materials

Contact Address: Rainer Zachmann, Ex-CGIAR (CIP, IITA), Kapellenstr. 28, 89079 Ulm, Germany, e-mail: rainerzachmann@hotmail.com

Austrian African University Network - Strengthening community-based research for river health and climate change mitigation in Eastern Africa

Andreas Bauer[1], Lorine Auma[2], Maureen Kabasa[3], Nzula Kitaka[2], Norah Mutekanga[4], Joel Onyango[3], Grace Ssanyu[4], Gabriele Slezak[1], Andreas Melcher[1]

[1]*University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. of Development Research, Austria*

[2]*Egerton University, Dept. of Biological Sciences, Kenya*

[3]*African Centre for Technology Studies, Research – Science Technology and Innovation, Kenya*

[4]*Kyambogo University, Dept. of Biological Sciences, Uganda*

Most urban areas in Sub-Saharan Africa depend on sustainable and resilient use of freshwater ecosystems, especially for their drinking water supply. However, the water quality of these ecosystems is often jeopardized by pollution from industry and agriculture, as well as the critically increasing effects of climate change. Water quality monitoring in Uganda is limited to physical and chemical indicators so far, which are considered short-term and highly inconstant drivers. Sustainable management of freshwater resources is challenging as it requires a holistic socio-ecological understanding of (1) the environment and (2) human interactions to enable the best inclusive decisions for mitigation and restoration measures. Our project focuses on one of Uganda's main River (Kafu) catchments around Kampala. The implemented multiple lines of evidence method identified agriculture, industry, urbanization, and climate change as the most critical drivers of freshwater and ecosystem degradation. Multiple lines of evidence have been drawn from international and local publications, expert judgment, community knowledge, and abiotic and biotic (benthic invertebrates) field data. A trans- and interdisciplinary cause-effect model, finalized in a participatory approach, allowed the transfer and facilitating of complex scientific results in a "Driver-Pressure-Status-Impact-Response" framework to a broader public. The key lesson learned, to respect aquatic ecosystems and their function of resilience, underlined the community-engaged and scientific relevance to identifying the best and most sustainable socio-ecological training programs and locally adapted recommendations to politicians, stakeholders, and decision-makers.

Keywords: Cause-effect models, community-based methods, freshwater ecosystems, multiple-lines of evidence, water quality, Uganda

Contact Address: Andreas Bauer, University of Natural Resources and Life Sciences, Vienna (BOKU), Inst. of Development Research, Peter-Jordan-Strasse 76/i, 1190 Vienna, Austria, e-mail: andreas.bauer@boku.ac.at

Cultural knowledge in child complementary feeding in agropastoral settings of northern Benin

Kouété Paul Jimmy[1], Ange Honorat Edja[1], Brigitte Kaufmann[2]

[1]University of Parakou, Rural Economics and Sociology, Benin
[2]German Institute for Tropical and Subtropical Agriculture (DITSL), Germany

The Benin Demographic and Health Survey recently revealed that 32 % of children under five are malnourished. Local nutrition practices and knowledge are increasingly seen as reliable solutions to the problem of malnutrition. However, little is known about the extent to which child nutrition is related to the interaction of local and external nutrition environments, as well as related beliefs and associated cultural knowledge. The present study aims to investigate conceptions and knowledge related to children's complementary feeding. Data were collected from mothers of children under five from the communities of Bariba, Peul and Gando in Banikoara and Nikki districts in northern Benin. Participant observations were conducted in 34 households of mothers with children to collect data on the provision and preparation of food for children and their consumption between 2021 and 2022. In addition, 6 focus groups were conducted with about ten mothers on stories and proverbs related to child nutrition. The findings showed local foods as porridge and dough are predominant in the three communities. The sauces served are usually made from dried local vegetables. The preparation and consumption of meat or fish is almost non-existent in Peul households, but is common in Gando and Bariba communities. In Peul communities, sauce preparation based on okra leaves mixing with crushed beans as vegetal protein containing food is rather common. Also, most of child mothers cooked a mixture of boiled sorghum flour and *moringa* leaves called dambou as special meals for diversifying household diets. In the Bariba communities, special children's meals made from external foods such as rice, pastas and couscous are particularly common. Furthermore, thirteen stories and proverbs collected meant that mothers' feeding practices are underpinned by: 1) the idea of 'taking care of the belly' of family members; 2) the valorisation of food or the attitude of 'not wasting food' (e.g. re-preparing leftover food); 3) the local notion of 'valued foods' (e.g. viewing some foods as sources of 'power' for children). These findings highlighted positive deviant knowledge and practices among targeted child mothers that are likely suitable for improving children's complementary feeding practices in neighbouring malnourished households or communities.

Keywords: Agropastoral settings, Benin, child feeding and nutrition, child mothers, food ethnography

Contact Address: Kouété Paul Jimmy, University of Parakou, Rural Economics and Sociology, Okedama, Parakou, Benin, e-mail: jimmykouetepaul@yahoo.fr

Social dynamics of food systems transformation

Online posters

Local food system resilience in context of shocks and crises: Vulnerabilities and responses of agroecology-based farmers in Peru, the United States, and Germany

Giovanna Chavez-Miguel[1], Antonio Gonzáles[2], Pia Gleich[2], Janika Hämmerle[2], Chiara Canettia[2], Rebecca Lynn Halfasta[2], Moritz Feuchtera[2], Dominika Buszydloa[2], Laura Schwarz[2], Imke Scheepstra[3], Stef de Haan[4], Raúl Ccanto[5], Stefan Sieber[1,2], Michelle Chevelev-Bonatti[1]

[1]Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SUSLand), Germany
[2]Humboldt Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany
[3]Freie Universität Berlin, Inst. for Latin American Studies (LAI), Germany
[4]International Potato Center (CIP), Andean Initiative, Peru
[5]Grupo Yanapai, Peru

Multiple crises have disrupted food systems globally in the last years. The shocks induced by the COVID-19 pandemic, coupled with the economic effects related to increased energy prices and shortages of fertilisers and agricultural inputs, affect farmers everywhere. By applying inductive, qualitative, and comparative research approaches, we investigate the effects of interlinked shocks and crises on local food systems from a farmers' perspective. We applied mixed qualitative field methods to voice farmers' perceptions about the effects of interrelated shocks and crises of farmers (n=25) belonging to agroecology-based local food systems of Peru, the United States and Germany. This study aims to: (i) understand the different crises scenarios and induced farmers' vulnerabilities; and (ii) identify the response mechanisms that farmers deploy in response. Results show that farmers in the three study areas experience multifaceted effects of the crises, mainly reduced access to inputs and labour, resulting in production decline, low incomes, and decapitalisation. Farmers' strategies and responses are understood with regards to their responsive capacities and within the socio-political environments that they are embedded, and thereafter analysed based on attributes of food system resilience. The main differences among our case studies related to the form of capitals (financial, social and human) that farmers have available for responding to shocks. Our findings demonstrate how strategies were successfully implemented where social resilience, i.e., stronger communal ties existed. We argue that the main potential for scaling agroecological local food networks, and thereby strengthen food system resilience, lies in

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improving the efficiency of existing short-length distribution channels and fostering trust-building and solidarity-based interactions between producers and consumers. Thereafter, we emphasise the need for more proactive policies aimed at promoting agroecological and localised production, as well as ensuring channels for commercialization, in order to enhance food systems resilience against recurrent shocks and crises.

Keywords: Farm-market interfaces, persistence, responsive capacities, social-ecological systems

M'inka, ayni and apachikuy: Social practices for food systems in crisis

Liza Melina Meza Flores[1], Claudia Heindorf[2]

[1]*San Ignacio de Loyola University, Environmental Engineering, Peru*
[2]*University of San Luis Potosí, Multidisciplinary Program in Environmental Sciencies, Mexico*

Andean social practices in Peru, such as the *mink'a*, *ayni* and *apachikuy* are based on solidarity, which seeks to guarantee the production and consumption of food for people in the countryside and also for their kin in the cities. The interweaving of traditional knowledge and social practices, as well as innovations can be effective in promoting the resilience of food systems. The aim of our work is to shed light on the social practices of cooperation for production (*mink'a* and *ayni*) and distribution of products (*apachikuy*) as examples of practices that are relevant in Peru, and to discuss their current potential to address food crises.

To achieve this, semi- structured interviews to different key actors were carried out in four Andean provinces in Peru to incorporate insight information about the use of these social practices pre-pandemic and during the lockdown and post-lockdown. An extensive literature review was also carried out. Based on this information, a SWOT analysis (strengths, weaknesses, opportunities and threats) was conducted. The analysis highlights the strengths and opportunities in terms of contributing to social tissues and providing support to vulnerable groups in times of crisis, while it reveals weaknesses and threats concerning the neglect and devaluation of these social practices by younger generations. Our conclusion is that these social practices contribute to sustaining food systems in critical situations, but require governmental programmes and academic research to ensure their continuity and promote their recovery and re-activation.

Given the limited research on the importance of these social practices, beyond their general description and ancestral uses, we recommend further research on the application of these practices and the measurement of their impact on food security and food sovereignty. A sound evidence base for the development of policies in Peru that promote resilient food systems is essential, as the country ranks first in food insecurity in Latin America.

Keywords: Community practices, COVID-19, food crisis, food security, solidarity practices

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Contact Address: Liza Melina Meza Flores, San Ignacio de Loyola University, Environmental Engineering, Av. Panamericana Sur 251, Lima 4 Lima, Peru, e-mail: lizameflo@yahoo.com

Understanding migration trends and livelihood vulnerability: A case study from Ghana

Franziska Jäckel, Terese Venus

University of Passau, Bioeconomy Economics, Germany

In West Africa, agriculture employs the majority of the rural population with increasing pressure related to climate change and its compounding impacts on livelihood. Due to these pressures, scholars have observed increasing streams of circular migration resulting in translocally organised networks between rural and urban regions. While previous research has investigated the dichotomous nature of rural-to-urban migration, our study understands migration and mobility from the research perspective of translocality. Migration of this nature can support rural households through the provision of remittances and knowledge transfer in regards to adaptation measures to reduce the impact of climatic changes. To understand the relationship between different patterns of migration motivated by climate change and household livelihood vulnerability, we estimate the livelihood vulnerability index to understand the three components of sensitivity, exposure and adaptive capacity. For our sensitivity component, we include climate data from the region in addition to household-level indicators. Then, we explore the causal effect of different patterns of migration and characteristics of the migrant on household vulnerability scores as well as other indicators related to household well-being (e.g. women's empowerment) using matching methods. Our case study focuses on 572 randomly sampled households and contains information on 3094 individual household members from Ghana's rural Northern and Eastern Regions, which represent two of the country's most important agricultural regions. Within our sample, over 53 % indicate farming as their most important economic activity. Over 63 % have noticed environmental changes within the last 10 years and more than 96 % see farming negatively affected by these changes. In total, over 75 % of the households have migrants, mainly migrating to Greater Accra and Ghana's Northern and Eastern Regions. We distinguish between several types of migration patterns and hypothesise that households with longer-term migrants will be less vulnerable, specifically with higher adaptive capacity and lower sensitivity scores, e.g. through knowledge transfer and monetary, as well as in-kind remittances. Further, we hypothesise that the effect of migration on household vulnerability is stronger for younger migrants. Our findings will have implications for internal migration policy and its role as an important livelihood diversification strategy in the face of climate change.

Contact Address: Franziska Jäckel, University of Passau, Bioeconomy Economics, Zuppingerstr. 11, 94078 Freyung, Germany, e-mail: franziska.jaeckel@uni-passau.de

Building resilience or missing specification? Crop and labour diversification in Southeast Asia

Eva Seewald, Oliver Schulte

Leibniz University Hannover, Institute for Environmental Economics and World Trade, Germany

Poverty and climate change are just two major problems among others the global south faces with severe impacts on wellbeing. According to the Global Climate Risk index, Vietnam and Thailand rank 6th and 9th respectively for the period from 1999–2018. Higher temperatures, greater variability in rainfall patterns and altered growing seasons negatively affect agricultural production and, thus, farmers' income. Poverty comes with multiple faces. Not only is it defined by a scarcity of monetary values like income but it also captures other aspects of life. To capture access to health services, education, and participation as basic features of a dignified life, researchers developed the multi-dimensional poverty index.

Researchers have investigated measures to mitigate the effect of weather shocks like droughts or unusual heavy rainfall. Results show that diversification in livelihoods and crops can help to alleviate the negative effect of weather shocks. However, most of the literature measures the impact of diversification strategies on income. There is a research gap measuring the impact of diversification, particularly crop diversification, on multi-dimensional poverty.

With this analysis we try to close this research gap by using a uniquely large socio-economic panel data set from Thailand and Vietnam capturing ten years from 2007 until 2017. It allows for the calculation of a multi-dimensional poverty index and the Simpson's index of diversification for crops and off-farm labour. In addition, the data set also allows to measure self-reported weather shocks. To capture the bias introduced by self-reported weather shocks and its connection to diversification, we use precipitation from the NASA.

Our results, using fixed-effects panel-regressions, show that heavy rainfall increases multi-dimensional poverty in Vietnam. This effect is mitigated by labour diversification. While crop income and labour diversification reduce poverty in Thailand, crop diversification increases poverty in Vietnam. Self-reported environmental shocks increase poverty in both countries while the effects are mitigated by crop diversification in Thailand but not in Vietnam. Interestingly, labour diversification reduces poverty in both countries, Thailand and Vietnam. Our results indicate that the risk management features of diversification must be cautiously weight against possible efficiency losses due to forgone specialisation benefits.

Contact Address: Eva Seewald, Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: seewald@iuw.uni-hannover.de

Power relations and socio-ecological resilience in small-scale farming systems: Learnings from a long-term research program

Akanksha Singh, Amritbir Riar, Marc Cotter, Eva Goldmann,
David Bautze, Beate Huber

Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

Socio-ecological resilience (SeR) is an integral aspect in enhancing farm system sustainability and this integration is being widely adopted in recent years in development projects. Multiple indicators are used to assess socio-ecological resilience of suggested solutions in farming systems or, to design projects with an aim to ultimately enhance SeR. However, the indicators or the suggested solutions remain largely technical; often overlooking the role that social solutions or power relations play in the long term in farming systems sustainability. There is growing evidence indeed that unequal power relations in agriculture are a threat to food security worldwide. Hence, there is a need to focus on equity when determining indicator or when developing solutions for sustainable food systems. We set up a long-term farming systems programme in 2007 in three tropical countries (India, Kenya and Bolivia) to compare organic and conventional management systems across multiple parameters. In all the countries we have been working with small-scale farmers on specific cropping systems (cotton, cacao and maize). The approaches of our programme have been interdisciplinary focusing on all the way from fundamental agronomic questions to participatory farmer research. Over the years multiple studies and analysis have been conducted within our programme to understand the socio-ecological dimensions of sustainable farming practices in our study areas. We will present compiled learnings of these studies with a focus on two of our study regions, India and Bolivia. We will particularly summarise the role that factors such as farmer networks, farmer cooperatives, caste and identity, motivation and extension services play (a) in understanding farming systems and, (b) in adoption of suggested solutions. Using these results, we will discuss additional parameters that need to be considered when assessing social-ecological resilience of farming systems, with a particular focus on power relations. We will take inspiration from the widely applied social-ecological system framework by Elinor Ostrom to present our approach. We suggest that considering such an approach is crucial to balance trade-offs and synergies in the process of improving sustainability of small-scale farming systems.

Keywords: Equity, framework, indicators, power relations, resilience, small-scale farmers, socio-ecological

Contact Address: Akanksha Singh, Research Inst. of Organic Agriculture (FiBL), International Cooperation, Ackerstrasse, CH-5070 Frick, Switzerland, e-mail: akanksha.singh@fibl.org

Local community preferences for ecosystem services: Tradeoff analysis for a biosphere reserve in southwestern Ethiopia

Lulseged Tamene Desta[1], Wuletawu Abera[2]

[1]*International Center for Tropical Agriculture (CIAT), Ethiopia*
[2]*The Alliance of Bioversity International and CIAT, Ghana*

Climate change and land degradation have contributed to the deterioration of the overall health of the earth undermining its ability to function in a sustainable manner. The increasing demand for agricultural products has been partly met by increasing cultivated land leading to competition between different land uses and users. In such circumstances the available supply of ecosystem services (ESSs) can dwindle, and the system will not be able to support the demand of the growing population. Such a notable example is being experienced in the Yayo Coffee Forest Biosphere Reserve (YCFBR) of southwestern Ethiopia. Large parts of the YCFBR rainforests and their wild coffee populations have been modified or destroyed due to rapid deforestation, conversion to agricultural land, introduction of new settlements and timber extraction in the past decades. These led to a huge loss of rich biodiversity undermining the benefits associated with the forest and wild coffee resources and impacting people's livelihoods as well as local and national economy. Developing participatory land management options involving the needs and aspirations of the local communities is essential to protect the biosphere and sustain its use. In addition, there is a need to balance the management and utilisation of the inherent natural capital and the associated demand of the community to ensure long-term sustainability. Such knowledge can enable the development of targeted and context specific land use and management plans for the YCFBR. This can be supported by understanding the perceptions, preferences and expectations of land users related to the ESSs and their distributions within the YCFBR. This study integrated earth observation and socio-economic survey tools to (a) analyse the supply of ESSs across the biosphere and its surroundings; (b) evaluate the preferences of local communities towards major ESSs across the biosphere continuum (demand; (c) analyse the tradeoffs and synergies between ecosystems services in relation to community needs and preferences, and (d) develop an optimal land use and management plan for the YCFBR and its surroundings. Such study is essential to guide informed decision making considering the available resource potential in relation to the needs and priorities of local communities.

Keywords: Ecosystem services, Ethiopia, land use optimisation, tradeoffs

Contact Address: Lulseged Tamene Desta, International Center for Tropical Agriculture (CIAT), Addis Abeba, Ethiopia, e-mail: lt.desta@cgiar.org

The road to recovery: Smallholder household resilience to food insecurity amidst climate-change and COVID-19-induced shocks

Esther Gloria Mbabazi[1], Awudu Abdulai[1], Enoch Kikulwe[2], Elisabetta Gotor[3]

[1]University of Kiel, Dept. of Food Economics and Consumption Studies, Germany
[2]The Alliance of Bioversity International and CIAT, Uganda
[3]The Alliance of Bioversity International and CIAT, Italy

The COVID-19 pandemic and the measures instituted to curb its spread had devastating effects on livelihoods in Sub-Saharan Africa where smallholder farmers were already grappling with the effects of climate change. The disruptions in transport and inaccessibility to both agricultural input and produce markets resulting from the lockdowns increased the susceptibility of the farming households to food insecurity. In Uganda, the government provided relief in form of a one-off supply of food and cash to a small part of the peri-urban population. In the absence of social protection, rural farming households in the country had to bank on their resilience capacity to cope with the myriad of shocks. The objective of this research was threefold; to analyse the effects of climate change and COVID-19-related shocks on the food security status of rural smallholder households, evaluate the determinants of their resilience to food insecurity amidst the shocks and, assess the role of their resilience capacity in facilitating recovery. The data used is from a panel of three waves of household surveys collected in western Uganda before the pandemic, during a lockdown and afterward. We employed factor analysis, structural equation modelling and probit models for the empirical analysis. The findings show that 40 % of the households consumed less diverse diets whereas 52 % experienced a reduction in food consumption per capita during the pandemic. Shocks including loss of employment, death of a relative due to COVID-19, disruptions in transport and increased prices of foodstuffs were associated with a decline in the household food security status. The coping strategies employed such as change in dietary patterns, reduced expenditure on foodstuff and distress sales of livestock as indicated by 34 %, 28 % and 10 % of the households respectively further threatened their food security status. Ownership of productive and non-productive assets and access to social safety nets such as remittances and belonging to associations were the major contributors to household resilience. Furthermore, household resilience was significantly and positively related to the likelihood of recovery of the food security status over time. Households with a higher resilience capacity index were better equipped to absorb and adapt to shocks.

Keywords: Climate change, COVID-19, food insecurity, households, recovery, resilience, rural, shocks, smallholder

Contact Address: Esther Gloria Mbabazi, University of Kiel, Dept. of Food Economics and Consumption Studies, Johanna-Mestorf-Str. 5, 24118 Kiel, Germany, e-mail: gmbabazi@food-econ.uni-kiel.de

Actor-network theory for eco-resources species *Ziziphus mauritiana* (Masau) management in Zimbabwe

Anyway Katanha, Itai Offat Manyanhaire

Zimbabwe Open University, Dept. of Geography and Environmental Studies, Zimbabwe

This paper presents a critical analysis of the applicability of the actor-network theory to natural resource governance in semi-arid regions which depend on specific eco-resource species such as *Ziziphus mauritiana* (Masau-zm) and its role in national policy integration using a case from Muzarabani area of Zimbabwe. Based on the Dambakurimwa community from Muzarabani the results revealed that natural resource governance is complex and the theory has self-regulatory characteristics. Rural resilience and sustainability benefit from initiatives that foster actor-network theory-based analysis of natural resource governance networks using a multipurpose fruit tree useful to a natural hazard-prone community in Zimbabwe. Many sub-Saharan countries are developing regulatory frameworks, policies, and laws that ensure fair and efficient management and trade of natural resources in remote areas. Networks resource governance, is characterised by the increased role of diverse actors that include state and non-actors as well as and external networks. The main thrust of networked governance is to develop synergies between diverse competence and knowledge bases to solve complex as well as interrelated challenges. In many developing nations, it has been well documented that the main challenge of natural resource governance like wild fruits is linked to the diverse interest of various actors directly or indirectly involved in the use of, trade, and overall management of the natural resource products. The involvement of different actors reflects multiple subsistence, commercial, social, ecological, and conservation agendas as well as multiple actors both state and non-state and all facilitating the same goal. The inclusion of diverse actors in the matrix results in natural resource governance of wild fruits being fragmented and at times engrossed in diverse sectors or being at the centre of polycentric institutions and actors that induce tensions, conflicts, and ambiguity that may degrade the resource. In an effort to comprehend this dilemma, systematic characterisation of the governance structures for diverse natural resource species is necessary. In respect, the characterisation of these governance types can aid in policy issues identification and development that further seeks policy attention.

Keywords: Actors, eco-resources, governance, network

Contact Address: Itai Offat Manyanhaire, Zimbabwe Open University, Dept. of Geography and Environmental Studies, Bindura, Zimbabwe, e-mail: offatmanyanhaire@gmail.com

Material and non-material contributions of rice agroecosystems to indigenous farmers in the Upper Baram, Malaysia

Alexander Hollaus[1], Christoph Schunko[1], Rainer Weisshaidinger[2], Poline Bala[3], Christian R. Vogl[1]

[1]*University of Natural Resources and Life Sciences, Vienna (BOKU), Dept. of Sustainable Agricultural Systems, Austria*

[2]*Agroecology.AT - Consultancy on Agroecology and Sustainability of Agricultural ystems, Austria*

[3]*Universiti Malaysia Sarawak (UNIMAS), Malaysia*

Traditional rice agroecosystems enrich the world's agricultural heritage and diversity of farming practices. The main output of these agroecosystems is the production of rice for food. However, traditional rice agroecosystems contribute to farmers in many ways beyond the material contribution of rice, including non-material contributions that are important to farmers' individual and cultural lives. This research aimed to understand the material and non-material contributions of swidden and wet rice agroecosystems to indigenous farmers in a traditional rice cultivation landscape in the Upper Baram, Malaysia, using the IPBES nature's contributions to people framework. In the year 2020, 43 semi-structured interviews were conducted with indigenous farmers in two villages to collect data, which were analysed using qualitative content analysis. The contributions of rice agroecosystems were deductively classified into the categories of the IPBES framework. The findings demonstrated that the rice agroecosystems support farmers through material contributions, including rice and non-rice food, and non-material contributions, such as supporting farmers' identity as well as contributing to knowledge transfer and a feeling of happiness. The rice agroecosystems are therefore more than just a source of food, as they also contribute to the social and cultural aspects of farmers' lives. The farmers also perceived differences between the rice agroecosystems. The wet rice agroecosystem is perceived as providing a higher rice yield with less labour-intensive farming practices. The swidden rice agroecosystem is associated with a greater variety of material contributions, such as the provision of building materials, firewood and more non-rice food, often found in the system's fallow land. Besides the beneficial contributions, a detrimental contribution of the swidden rice agroecosystem is the tiring and difficult farming practices, such as weeding or slashing the field. Due to the different contributions, most farmers prefer the wet rice

Contact Address: Alexander Hollaus, University of Natural Resources and Life Sciences, Vienna (BOKU), Dept. of Sustainable Agricultural Systems, Vienna, Austria, e-mail: alexander.hollaus@boku.ac.at

agroecosystem because of the economic and lifestyle benefits. This preference, combined with ongoing socio-economic changes in the area, could lead to a shift from swidden rice cultivation to more permanent wet rice cultivation. However, the traditional swidden rice agroecosystem may also be maintained as a risk mitigation measure in case the wet rice agroecosystem fails to produce sufficient rice.

Social and environmental impacts of Maryland oil palm plantations on forests biodiversity and community livelihoods in Liberia

Richard Sam

Sustainable Development Institute, Community Rights & Corporate Governance Programme, Liberia

Liberia holds 44.5 % of the remaining portion of the Upper Guinean Rainforest in West Africa which is home to critically endangered forest elephants and western chimpanzees, the forests are of vital importance for the livelihoods of millions of West Africans and provide key ecosystem services of local and global importance for food systems transformation and agroecology. Liberia's efforts toward land reform through legislation and policies recognise communities' rights to own and manage their customary lands and resources. These include the National Forestry Reform Law of 2006, the Community Rights Law Concerning Forest Lands of 2009, and the Land Rights Act of 2018. In May 2022, the Sustainable Development Institute (SDI) - Friends of the Earth Liberia team researched the Social and Environmental Impacts of Maryland Oil Palm Plantations in Liberia. 23 Key Informant Interviews and 10 focus group discussions in seven communities in and around the MOPP plantation. They included farmers, (contract) workers, MOPP staff, local authorities, women and youth leaders, the Environmental Protection Agency (EPA) Inspector, the civil society head, and the gender coordinator of Maryland County. The team cross-checked information with formal documents as much as possible and took photographs and GPS locations of areas of deforestation, pollution, and conflict. Research finds that land conflict and deforestation include several negative impacts on communities. MOPP has not respected land tenure rights or followed free prior and informed consent (FPIC) standards, including resettlement without reparation and destruction of farms and old towns without (sufficient) compensation or restitution. Communities lost their farms during MOPP land acquisition and clearance and villages were identified as 'village de squatters', resulting in limited access to farmland increases food insecurity, and fewer cash crops to support family incomes. MOPP destroyed high conservation value areas and destroyed secondary forest regrowth which affected important biodiversity areas. MOPP is one of the four large-scale industrial palm oil plantations in Liberia. Situated in Maryland County, it has a palm oil mill in a joint venture with Golden Veroleum Liberia (GVL). Its 2011 concession agreement includes 8,800 hectares for industrial palm oil plantations.

Keywords: Biodiversity, climate change, community rights, deforestation, ecosystem services, food security, human rights, land rights, livelihood

Contact Address: Richard Sam, Sustainable Development Institute, Community Rights & Corporate Governance Programme, Duazon Village, Robertfield Highway, Margibi County , 1000/10 Monrovia, Liberia, e-mail: richardsam842017@gmail.com

Identifying success factors of forest landscape restoration: A case study of Tchamba prefecture Togo

Kossi Hounkpati[1,2], Kossi Adjonou[2], Hamza Moluh Njoya[1], Kouami Kokou[2], Stefan Sieber[3,1], Katharina Löhr[1,3]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*

[2]*University of Lomé, Forestry Research Laboratory, Climate Change Research Centre (CRCC), Togo*

[3]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany*

Forest landscape restoration (FLR) is a current key approach to improving human well-being and recovering ecological integrity. There is a need to create a flexible and innovative approach to FLR that promotes participatory and adaptive management that considers the aspirations of populations. However, facing the challenges of FLR implementation, it remains important to identify success factors of this approach. The objective of this study is to identify the factors that contribute to the success of FLR activities based on the perception and preference for innovation among farm households in Tchamba Prefecture (Togo). The methodological approach for data collection was based on individual interviews and focus groups with agricultural households in the Tchamba prefecture. A representative sample of 494 households was surveyed. Descriptive statistics were performed. The results reveal that over 89 % of households perceive restoration through reforestation as an economic investment for the future, while 5.46 % perceive it as a means of safeguarding and enhancing the value of the land, and 4.08 % as a means of conserving species for future generations. Among respondents, 88 % agreed with the urgency of planting trees to slow down the decline in vegetation cover and the retreat of forests, as perceived by more than 66 % of respondents. Key local initiatives such as community forest creation, agroforestry, and forest planting account for over 90 % of FLR innovations. Also, the results indicate a strong motivation among farm households to adopt forest restoration innovation to test new opportunities and to be pioneers in the implementation of new restoration practises for improved economic returns. However, factors such as lack of land ownership, reduced cultivable space, and transhumance are the main demotivating factors for those involved in restoration in the area ('non-natives'). These results imply an economic perception of restoration, an awareness of forest cover loss and local innovations of farm households in FLR. Consideration of community forestry strategies could help safeguard the biodiversity and native forests of the area. The strengthening of innovative agroecological practises can help to strengthen the economic level and the well-being of the farmers in the Tchamba Prefecture.

Keywords: Economic perception, forest innovation Tchamba Prefecture, forest landscape restoration

Contact Address: Kossi Hounkpati, Leibniz-Centre for Agric. Landscape Res. (ZALF), Müncheberg, Germany, e-mail: kossi.hounkpati@zalf.de

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Designing socio-ecological landscapes for sustainable outcome: evaluating land-use options on ecosystem-service provisioning in south-western Ghana

Evelyn Asante-Yeboah[1], HongMi Koo[1], Stefan Sieber[2], Christine Fürst[1]

[1]*Martin Luther University, Sustainable Landscapes Development, Germany*
[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

Landscape modification through socio-economic activities is rampant in the south-western part of Ghana, threatening the region's landscape sustainability. Offsetting these threats requires an appropriate approach that can support land-use actors to better design the landscape towards enhanced ecosystem service (ES) provisioning, ensuring continued usage and profitability. This study adopted the geo-design approach, combining stakeholder perspectives and spatially explicit simulations to evaluate land management strategies on ecosystem service provisioning in south-western Ghana. Baseline datasets of land-cover maps and locally relevant ES (Food, fuelwood, marketable products, species diversity, and soil quality regulation) were captured through GIS methodologies and stakeholder workshops, respectively. Seven new land-use options (urban green, mangrove restoration, selective land preparation, rubber mixed stands, open space restoration, relay cropping, and soil conservation) were identified based on selected land-cover types on the study landscape. Combining the land-cover types and land-use options generated land management strategies that were translated into land-use scenarios under stated conditions. The developed land-use scenarios were subjected to a GIS web-based simulation platform where land-use patterns were rearranged to reflect the land-use options embedded in the land-use scenarios. Next, the land-use scenarios were evaluated against the locally relevant ecosystem services, and results were viewed in maps and ES balance tables. Strategies for the effective implementation of land-use scenarios were collectively discussed. The results, based on participants' perceptions, showed land-use options to exhibit higher capacity to provide ecosystem services compared to the current land-cover types except for rubber mixed stand, which was found to exhibit less capacity to provide marketable products compared to the current land-cover type. However, the simulated land-use scenarios resulted in synergies between land-use options and ES provisioning. Participants perceived inclusive collaboration planning among multiple land-use actors on the landscape as an effective means for successfully implementing land-use options. Based on this result, we could infer that this approach of geo-design is a guide to landscape planning in complex socio-ecological dynamic landscapes and has the potential for improving local acceptability and adaptability for sustainable outcomes.

Keywords: Geo-design, land-use options, landscape sustainability, spatial simulations, stakeholder perceptions

Contact Address: Evelyn Asante-Yeboah, Martin Luther University, Sustainable Landscapes Development, Von-Seckendorff-Platz 4, 06120 Halle (Saale), Germany, e-mail: eveyeb84@gmail.com

Drivers, enablers and barriers for wider adoption of agroecological farming practices in Ethiopia: A case of vegetable production

Yidnekachew Zewde, Ralph Roothaert, Wubetu Legesse, Amha Besufkad

World Vegetable Center, Ethiopia

The conventional vegetable production systems promote wider applications of chemical fertiliser and synthetic pesticides to maximise crop yield. Studies also show that applications of such chemical inputs have reached an alarming rate and it has created eminent threat on the health of soil, plants, animals and humans. Therefore, a sustainable production system that promotes the adoption of agro-ecological practices has paramount importance to ensure improved health for the planet and people. This paper examines the main drivers, barriers and rates of adoption of agro-ecological practices in central highlands of Ethiopia. The findings from the study showed that there was limited awareness and scant application of agro-ecological practices. The adoption process is mainly determined by agronomic, socio-economic, institutional, financial, socio-cultural and market related factors. During the two and half years of intervention in three districts of Ethiopia, the number of farmers who adopted more than five RAs has increased by almost 62 %. The most widely adopted practices include the use of vermicompost, bio-slurry, crop rotation, conventional compost, neem extract for pest control, intercropping and improved crop varieties. On the other hand, the least adopted RAs constitute the application of drip irrigation, mulching, protected cultivation, green manuring, and biopesticide. The main supply-side determinants for adopting a particular practice include the cost of adoption, accessibility to farmers, scale of adoption, type of crop, relative availability of inorganic inputs (chemical and fertiliser), skills required for adoption, and institutional support system. A multiple regression analysis on those determinants implies that age of farmer, level of education and frequency of attending training were found to be enablers of adoption. However, the number of practices adopted by a farmer and his/her land holding size exhibit an inverse relationship: this means smallholders have got higher propensity to intensify. The barriers to adoption include limited access to organic inputs and absence of a market system that differentiates vegetables produced in an agroecological way. Therefore, to enhance the rate of adoption and make impact at scale, further research and development interventions should focus on factors that empower, enable and drive the adoption of agroecological practices.

Keywords: Agroecological practices, barriers, enablers, people & planet health, vegetable production

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Contact Address: Yidnekachew Zewde, World Vegetable Center, Socioeconomic Research and Enabling Impact, Gurd Shola Street, 5689 Addis Ababa, Ethiopia, e-mail: yidnekachew.zewde@worldveg.org

ID 392

Factors associated with the adoption of diversified farming systems: A global meta-analysis

Andrea Cecilia Sanchez Bogado[1], Sarah Jones[1], Natalia Estrada-Carmona[1], Damien Beillouin[2], Cecile Bessou[3], Bruno Rapidel[4]

[1]*The Alliance of Bioversity International and CIAT, Multifunctional landscapes, France*
[2]*CIRAD, Martinique*
[3]*CIRAD, Australia*
[4]*CIRAD, UMR Agrosystèmes Biodiversifiés, ABSys, France*

Diversified farming systems have been recognised as effective strategies for achieving sustainable food production by providing economic, environmental, and social benefits to farmers, while mitigating the negative impacts of climate and market changes. However, despite the growing evidence of the advantages of diversified systems, many farmers worldwide usually tend to adopt simplified farming practices like monocultures. To better understand the drivers and constraints behind the adoption of diversified farming systems (e.g., agroforestry, intercropping, crop rotation) in different sub-regions around the world, we conducted a global meta-analysis of 79 peer-reviewed articles that quantitative compared bio-physical, social, and economic characteristics of adopters and non-adopters of diversified farming practices. Our database included more than 30 factors that may influence the adoption of 8 diversified systems, in 30 countries on five continents. Our overall results showed that, on average, the adoption of diversified farming systems was significantly associated to farmer education, farmer gender, farmer age, farm size, land tenure, access to credit, access to training, access to agricultural extension, labour availability, but the strength and direction of these correlations varied across different farming systems. Additionally, the meta-analysis indicated that the factors driving and constraining the adoption of diversified farming systems vary across different sub-regions, with socio-demographic factors being more important in developing regions. Our results provide quantitative and robust evidence of factors that encourage and limit the adoption of diversified farming systems. These findings can guide researchers and policymakers develop targeted strategies that are better suited to local agricultural and cultural contexts and promote the widespread adoption of diversified farming systems. The insights of this meta-analysis have significant implications for achieving sustainable food production and improving the livelihoods of farmers around the world.

Keywords: Adoption, constraints, diversified farming systems, drivers, meta-analysis

Contact Address: Andrea Cecilia Sanchez Bogado, The Alliance of Bioversity International and CIAT, Multifunctional landscapes, 1990 boulevard de la lironde, 34370 Montpellier, France, e-mail: andrea.sanchez@cgiar.org

A social perspective on on-farm tree functions, drivers of deforestation and land degradation: Togolese farmers perceptions

Hamza Moluh Njoya[1], Kossi Hounkpati[1], Kossi Adjonou[2], Kouami Kokou[2], Stefan Sieber[1], Katharina Löhr[1]

[1]*Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany*
[2]*University of Lomé, Forestry Research Laboratory, Climate Change Research Centre (CRCC), Togo*

Deforestation and land degradation remain major, environmental, economic as well as social threats across the world. The present study reveals a social perspective on on-farm tree functions. In this context, it is assumed that perceptions of on-farm tree functions could play an important role in shaping the decision-making process for the entire agroecosystem. Therefore, looking at farmers when approaching on-farm tree functions is indispensable. This study investigated farmers' perceptions of the importance of on-farm tree function, drivers and effects of deforestation and land degradation in the Central region of Togo. We used a household survey coupled with focus group discussions to capture farmers' perceptions of deforestation, land degradation and on-farm tree functions. A total of 490 households were interviewed using a structured questionnaire and eight focus group discussions involving 21 farmers each (a total of 168 participants). The household survey revealed that the major causes of deforestation and forest degradation perceived by farmers included agricultural activities (85 %), population growth and urbanisation (71 %), fuel wood (56 %), and climate change (47 %). Land degradation evolved from the uncontrolled use of fertiliser (57 %), deforestation itself (57 %), lack of rain (56 %), extreme heat (41 %), inappropriate farming practices (36 %), and non-use of farmyard manure (8 %). The analysis also reveals that the perceived importance of two on-farm tree functions could predict the integration of trees on the farm: "income improvement" and "fuel wood". The study concluded that strengthening the importance of the "income improvement" function in farmers' minds can stimulate the plantation of trees. In the context of the implementation of restoration programs, investigating farmers' perceptions can significantly contribute to a bottom-up approach to sustainable forest landscape management.

Keywords: Deforestation, farmers' perceptions, land degradation, on-farm tree functions, social perspective

Contact Address: Hamza Moluh Njoya, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Münchehofer Weg 75, 15374 Müncheberg, Germany, e-mail: Hamza.Moluh-Njoya@zalf.de

Narratives, interests, and actors in forestry-SDG interactions: A systematic literature-based discourse analysis

Dominic Ahrens

Dresden University of Technology, International and Tropical Forestry, Germany

Forests support life on Earth through vital ecosystem services that are crucial for human well-being and sustainable development. Accordingly, forestry and forest landscapes are pivotal to achieving Agenda 2030 and the associated Sustainable Development Goals (SDGs). At the same time, implementing the SDGs is affecting forest quantity and quality. This holds particularly true for the Global South, facing high deforestation and forest degradation rates, often driven by forest conversion to agriculture. Enormous challenges and opportunities come with this interdependency and careful management is required to safeguard future sustainable development. The purpose of this study is to scrutinize discourses on forest-SDG interactions through an actor-centered perspective. As such, the study aims to critically shed light on SDG trade-offs and synergies in forest landscapes, the relevant actors' interests and narratives, and the conflicts among them. The analysis consists of two parts: (1) the mapping of thematic blocks shaping the forest-SDG discourse along with the associated trade-offs and synergies therein; (2) the identification of the corresponding actors, their interests, and narratives. Methodologically, the study deploys a systematic review of literature that addresses forest-SDG interactions from three angles: (1) the practical development politics discourse, (2) the corporate sector discourse, and (3) the scientific discourse, including the three major subcategories in nature, society, and technic. The results of the study will be presented at the conference with the overall objective to enrich the scientific and public discourse, as well as the practical decision-making process on SDG trade-offs and synergies in forest landscapes in the Global South.

Keywords: Forest, forest governance, forest landscape, interaction, SDGs, sustainable development goals, synergy, trade-off

Contact Address: Dominic Ahrens, Dresden University of Technology, International and Tropical Forestry, Pienner straße 7, 01737 Tharandt, Germany, e-mail: dominic.ahrens@tu-dresden.de

To maintain vegetable agro-biodiversity for nutrition security: insights from ethnic minorities in northern Vietnam

Phuong Thi Nguyen[1], The Ky Hoang[2], Huong T.M. Pham[2], Kees Swaans[2], Paul C. Struik[1], TjeerdJan Stomph[1]

[1]*Wageningen University and Research, Plant Sciences, The Netherlands*
[2]*The Alliance of Bioversity International and CIAT, International Centre for Tropical Agriculture, Vietnam*

Vegetables are crucial elements to ensure food and nutrition security. Ethnic minority communities in Northern Vietnam are the key holder of vegetable diversity but are also suffering from low nutrient intake and nutrition-rich food crises. Home-grown crops, including vegetables, are the major source of daily food and/or income that on which farmers have sovereignty and easy access. This study aimed at exploring the associations of environmental, socio-economic and agro-ecological characteristics, and seed diversity with the current vegetable agro-biodiversity in different ethnic minority communities in Northern Vietnam. Mixed methods included a quantitative household survey (409 farmers), qualitative farmer focus group discussions (13 FGDs) and key informant interviews (31 stakeholders) executed in 2019–2020. Variable importance evaluation was implemented to select the most important variables using projection predictive variable selection approaches by R package projpred v2.4.0. Bayesian inference approach was employed using R package brms v2.19.0 for the final analysis with the dependent variables being the total number of vegetable crops grown per household and the farmer's decision to source seed from external sources. Given the rich diversity of vegetables at landscape and community levels, diversity was quite modest at the household level, and a large variation in crops grown was observed among households within and between ethnic communities, reflecting households' preference diversity. A larger cropping land but not land for vegetables, more diversity of seed sources, better access to information, and home gardens supported a higher diversity of vegetables. In addition, vegetable availability was highly seasonal, and there were critically lean periods for vegetable availability which hints at an important shortage of vegetables for home consumption. Regarding farmers' seed choice, when starting materials needed were more diverse and given farmers' trust in seed sources, they intended to seek seed from external sources (i.e., involvement in integrated seed systems). Also, if vegetables were primarily grown for home consumption, the self-saved seed was prioritised. We recommend that it is necessary to enhance farmers' access to information, and diversification of reliable seed sources via bolstering an integrated seed system, and empowerment of local market channels for enhanced seed and vegetable diversity.

Keywords: Bayesian, ethnic minority, integrated seed system, nutrition security, seed source, vegetable diversity

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Contact Address: Phuong Thi Nguyen, Wageningen University and Research, Plant Sciences, Bornsesteeg, 6708PD Wageningen, The Netherlands, e-mail: thiphuong.nguyen@wur.nl

Socio-ecological interaction of rural agricultural system surrounding conservation area: Case study from Jepara regency, Indonesia

Jannatul Ulya, Arya Hadi Dharmawan

Bogor Agricultural University, Dept. of Communication Sciences and Community Development, Indonesia

More than half of Indonesia's area is a forest area. In the forest area, there are a variety of natural resources as a source of livelihood for social system. But, since the change in status to a conservation area, the social mission for the welfare of farmer households around the area has become in conflict with the ecological mission. This purpose of this research to analyse the types of socio-ecological interaction that occur in rural households around conservation area in Indonesia by taking the case of conservation area in Jepara Regency. Data collection in this research was carried out by distributing questionnaires, in-depth interviews, and observation. The collected data was then analysed using mixed method.

The results of this research show that there are three types of socio-ecological interaction in conservation area namely, neutral socio-ecological interactions both for the local people and the forest ecosystem, limited uses of natural resources utilisation with very minimal impact to forest ecosystem, exploitative socio-ecological interactions from human being to forest resources. The difference between types of the interaction is seen from the identification of the initial question regarding their existence in the conservation area, namely whether or not whether they have entered the conservation area. Then, the analyses continue on the types of natural resources utilised, the frequency of natural resource utilisation, until the quantity of natural resources utilised. The important result from this research highlights the facts that although the awareness of the ecological mission is understood by the farmer households around conservation area, but the economic dimension still plays a role for households to use of natural resources from the conservation area.

Keywords: Agricultural-forest interaction, Indonesia, livelihood, natural resources, smallholders

Contact Address: Jannatul Ulya, Bogor Agricultural University, Department of Communication Sciences and Community Development, Grogolan village 03/02 dukuhseti, 59158 Pati, Indonesia, e-mail: 27112001ulya@apps.ipb.ac.id

Climate change, translocal migration and adaptation of rural farm households in Arochukwu, southeast Nigeria

IKENNA EJIBA, ADEOLA OLAJIDE

University of Ibadan, Dept. of Agricultural Economics, Nigeria

The climate change phenomenon portends a huge burden to many communities in the global south, and continues to impact farming households who depend on agriculture for their sustenance. Farming households especially in the rural areas have no choice than to adapt even in the midst of slow-onset events. This study therefore assessed translocal patterns and networks; and examined how translocal migration influence adaptation to climate change in Arochukwu, Southeast Nigeria. To achieve the objective, a multistage sampling technique was used in selecting 387 migrant and non-migrant farming households, while a baseline survey was used in data collection. Data collected was analyzed using descriptive and empirical methods. Result of the analysis suggests that majority (40.96 %) of translocal migrants migrated to towns and cities within the state (Abia), 30.12 % of the migrants moved to cities within the Southeast, 24.1 % migrated to cities outside the Southeast, while 4.82 % migrated internationally. In terms of translocal networks and exchanges, result indicate that migrants at urban destinations send more money (46.01 %) and less food/goods (29.75 %) to their households in the place of origin, while the household in the rural area send more food/goods (51.28) and less money (26.19 %) to the migrant at destination. In terms of adaptation and response to climate change variability, more translocal migrant household members migrate to urban areas (28.21 %) during off farm seasons; while more non-migrant household members migrate to rural areas (39.72) during off farm seasons. The t-test result performed to compare the mean adaptation between translocal migrant and non-migrant household's show that a significant difference exists between the two groups. Furthermore, the logistic model analysis showed that translocal migration significantly and positively influence adaptation. The study calls for a robust approach in the climate change and migration policy that will take translocal networks into consideration due to its potentiality for vulnerable households in the place of origin.

Keywords: Adaptation, climate change, translocal migration

Contact Address: Ikenna Ejiba, University of Ibadan, Dept. of Agricultural Economics, 3B Close, Karu, Abuja, 900104 Abuja, Nigeria, e-mail: victorejiba@yahoo.com

Comparative analysis of the agroecological transition through the prism of the territory concept: Two case studies in Senegal

Dié-Yacine Ka[1], Raphael Belmin[2], Astou Diao Camara[1], Aminata Niang Diene[3], Marc Piraux[2]

[1]*Senegalese Agricultural Research Institute (ISRA), BAME, Senegal*
[2]*Agricultural Research for Development (CIRAD), Senegal*
[3]*Cheikh Anta Diop University of Dakar (UCAD), Fac. of Geography, Senegal*

In Senegal, various actors (scientists, politicians, farmers, civil society) are currently behind initiatives in favour of agroecology and are involved in several fields such as technique experimentation, product market and advocacy. However, the agroecological transition struggles to reach all actors and to settle uniformly across the territories. Even when initiatives emerge, they remain isolated and dispersed in through time and space. According to the theoretical and empirical literature, taking into account the territorial scale would be necessary to analyse and implement change in a sustainable way.

Thus, this thesis uses the concept of 'territory', and questions the way in which it can be a driving force or an obstacle to an agroecological transition in Senegal. It is in line with the 'sustainability transitions' research field, particularly in the geography of transitions, in order to take into account the socio-spatial character of change. To address the problem, two case studies were chosen to represent the diversity of territorial functioning and the trajectories that agroecology can take: the municipalities of Ndiob and Darou Khoudoss. The methodology of 'territorial diagnosis' was chosen in order to analyse agroecology in time and space, the innovations and the determinants of their development, and finally to define anticipation perspectives in a collective manner to enable local actors to organise the transition within their territory. Anchored in a comparative and participatory approach, it is based on a combination of tools, such as semi-structured interviews, field observations, stakeholder mapping and anticipation. Through these theoretical and methodological decisions (conceptual frameworks, empirical case studies in a Southern context...), the study offers original answers to the limits of current research on agroecological transition.

The progress made during the first year of the thesis has yielded field results in regards to: the analysis of the agroecological intervention of various actors; the analysis of the institutional landscape and the actor network (alliance, power, conflict); the state of the art of technical, organisational and institutional innovations; the collective identification of territorial issues using a zoning system based on the accounts of different actors.

Keywords: Accompaniment, agroecological transition, Senegal, territory

Contact Address: Dié-Yacine Ka, Senegalese Agricultural Research Institute (ISRA), BAME, Dakar, Senegal, e-mail: dieyacine.ka@isra.sn

Energy-water-food nexus

Renewable energy and circular economy in the frame of water-food-energy nexus

Online posters

Unpacking stakeholder perceptions on challenges for increasing adoption of solar powered irrigation systems in India: A Q methodology study

Aditya Korekallu Srinivasa, Dagmar Mithöfer

Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany

Solar powered irrigation systems (SPIS) are seen as a means of increasing the share of renewable energy use in India, as agriculture is one of the main users of energy, with more than 30 million pumps, most of which run either on electricity (more than 60 % of which is coal-based) or diesel. The government's efforts to promote the adoption of SPIS by implementing the policy "PM -KUSUM", which provides subsidies on up-front costs, but have not delivered expected results due to low adoption of SPIS. The extent of adoption of technologies, including SPIS, also depends on stakeholder inter-actions and their perceptions of the technology itself as well as supporting infrastructure including policy settings. Inability to accommodate potential users' concerns in the policies could hamper technology adoption. In this paper, we use the Q method to examine the shared views of stakeholders on challenges for increasing the adoption of SPIS. Literature on the subject indicates that there can be substantial heterogeneity in the perceptions even within stakeholder groups, and functional classification based on perceptions through Q method can provide a richer description of viewpoints, which policy makers can address. To capture the discourse on challenges to the adoption of SPIS, in addition to review of published literature, we conducted 14 in-depth inter-views with different stakeholders. We shortlisted 60 statements and narrowed down and selected 20 unique and non-overlapping statements from these, followed by ex-pert review to ensure that statements fully represent the breadth of perspectives on the topic. In a next step 30 purposefully selected respondents representing all stakeholder groups (farmers, researchers, officers of Ministry of new and renewable energy, en-gineers from utilities distributing power, input dealers, pump retailers, and service providers, line department officials) ranked and sorted the 20 statements on a 7-point bipolar agree-disagree scale. The collected data were subjected to by-person factor analysis to extract three distinct viewpoints on the challenges for expansion of SPIS. We observed heterogeneity in viewpoints within the stakeholder groups. We identi-fied consensus statements indicating agreements and distinguishing statements that indicate differences in viewpoints across factors, which can guide future policies for out-scaling SPIS.

Keywords: Operant subjectivity, Q method, solar powered irrigation systems, stake-holder analysis

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Automated national biomass profiles for sub-Saharan Africa: Data for circular economy

Sebastian Semella, Fabian-Constantin Sittaro,
Friederike Naegeli de Torres

German Biomass Research Center (DBFZ), Germany

Utilising agricultural by-products for energy production or material use can help diversify income opportunities for small-scale farmers in rural communities in the Global South. This increased income can then be reinvested, subsequently improving yields and enhancing food security. Furthermore, circular farming practices maintain soil health by applying by-products like bio-fertilizers or bio-char from biomass use. However, a bioeconomic transition towards advanced smart-farming practices and the optimal use of agricultural by-products requires policy implementation and stakeholder engagement. Therefore, rapid assessment of national key indicators and national and regional biomass availability is an essential first step for informed decision-making and continuous monitoring.

The national biomass potentials are assessed at the Deutsche Biomasseforschungszentrum gGmbH (DBFZ) using an automated workflow with R markdown. The process involves identifying relevant data and querying APIs from international databases to compile key biomass information from various sources in a structured manner. More specifically, key figures and trends on the social-economic status and the natural resource base are identified. These include data on the most relevant crops, quantitative assessment of agricultural by-products, and animal excreta. The National Biomass Profiles resulting from this compilation and data review contain not only the current biomass potentials but also time series allowing analyses of interannual production stability.

Automated data updates will allow decision-makers and local stakeholders to track the key figures gathered. Linking this information with an automated mapping tool based on IFPRI SPAM data shows patterns of spatial biomass production on complementary maps. Thus, it serves as a decision-support tool, such as identifying suitable regions for implementing circular economy activities, including the installation of pyrolysis and biogas plants.

Keywords: Automatic mapping, circular economy, fact sheet, IFPRI SPAM, R markdown, sub-Saharan Africa

Climate justice in transforming land-use systems for food and renewable energy

Hussein Wario[1], Ann Waters-Bayer[2]

[1]*Center for Research and Development in Drylands, Kenya*
[2]*Agrecol Association, Germany*

With the growing global awareness of the climate crisis and the need for transition to renewable energy, governments and investors – including many in Europe – have recognised that the drylands in the tropics are highly suitable for generating wind and solar power. Many project planners regard these areas as "empty wastelands", reflecting a prejudice since colonial times that the drylands are marginal to the economy. Yet these areas are important livelihood assets for diverse groups of pastoralists, hunter-gatherers and crop farmers who have long used the land as a common pool resource to produce and/or harvest food for their families and the market. Large-scale land acquisition for energy projects will expand in the rush to produce not only wind and solar power but also green hydrogen – a trend that intensified with the war in Ukraine. The energy projects in the drylands are displacing local people from their land, disadvantaging particularly pastoralists by blocking access to pastures and hindering movement between them. This reduces pastoralists' ability to be resilient to climate change through herd mobility. In most of Africa, government do not recognise communal tenure as a legitimate form of land ownership. Therefore, during energy project planning, the local landusers' rights are ignored. They are not sufficiently informed about the plans and cannot defend their rights or negotiate adequate compensation. They did not cause the energy crisis but they – and their food systems – have become victims of climate injustice. This paper focuses on a study of land acquisition in the Kenyan drylands for investment in renewable energy. The study explored how some pastoralist groups are defending their community rights to their land. It identified the type of research that can help local people gain evidence about the value of their food-production systems and their contribution to the economy and ecosystem services, which puts them in a better position to negotiate sharing of the land and the benefits from energy generation. In the necessary transition to renewable energy worldwide, the challenge is to find synergies between production of sustainable energy and production of food to sustain local livelihoods.

Keywords: Co-existence, drylands, food production, land acquisition, pastoralism, renewable energy

From waste to wonder? Scaling the off-farm production of organic and biofertilisers in Africa: A scoping study

PIERRE ELLSSEL[1], FORTUNATE NYAKANDA[2], STÉPHANIE SAUSSURE[3], HAMADA ABDELRAHMAN[4], NADEGE AMIZERO[5], FATIMAH VON ABUBAKARI[6], ESTHER KOOPMANSCHAP[7], IOANNIS DIMITRIOU[8], HELENA POSTHUMUS[7], BERNHARD FREYER[1]

[1]*University of Natural Resources and Life Sciences, Vienna (BOKU), Dept. of Sustainable Agricultural Systems, Div. of Organic Farming, Austria*

[2]*Zimbabwe Organic Producers and Promoters Association Trust, Zimbabwe*

[3]*Natural Resources Institute Finland (LUKE), Finland*

[4]*Cairo University, Soil Science, Egypt*

[5]*Environmental Consultant, Rwanda*

[6]*University of Cape Coast, Department of Agricultural Economics and Extension, Ghana*

[7]*Wageningen University & Research, Wageningen Centre for Development Innovation, The Netherlands*

[8]*Swedish University of Agricultural Sciences, Sweden*

The Covid-19 pandemic and Russia's war against Ukraine have triggered a global crisis in the availability, timely delivery and price stability of food and agricultural inputs, especially inorganic fertilisers. However, simply expanding the production of inorganic fertilisers may fail the complexity of the problem, such as soil degradation and respective soil and plant health issues.

Initiated by the DG INTPA of the EU-COM, a scoping study was established to better understand the opportunities and challenges in scaling the off-farm production of organic (OF) and biofertilisers (BF) in Africa and related (policy) recommendations. The scope includes - among others - a description of the current state of production, origin of organic matter, quantities produced and prices, current state of demand and use, and an assessment of the potential supply of organic matter.

A mixed-methods approach was used, combining a literature review and about 80 qualitative interviews with key informants spread across the subregions of Africa with a total of 12 countries. Interviewees included various stakeholders such as producers, researchers, farmer organisations, advisory services, policy makers and farmers.

We identified diverse activities and business cases where entrepreneurs are recycling residues from agro-processing into compost and other OFs, including smaller quantities of municipal organic waste, crop production residues, animal manure, and sometimes mixing with inorganic fertilisers and/or bio-

Contact Address: Pierre Ellssel, University of Natural Resources and Life Sciences, Vienna (BOKU), Dept. of Sustainable Agricultural Systems, Div. of Organic Farming, Gregor-Mendel-Strasse 33, 1190 Vienna, Austria, e-mail: pierre.ellssel@boku.ac.at

char, as well as liquid fertiliser from human urine. However, the quantities of OFs currently produced are relatively small, the demand for alternatives is high, but prices are also comparatively high. In the case of biofertilisers, successful activities of rhizobia production and application exist; for other biofertiliser types, as well as OF verifiable results of product efficacy are lacking. Much untapped potential exists (e.g., urban/value chain waste), but collection systems, standardisation, quality enforcement, governmental frameworks/regulations, technical assistance, integration into education/training and research and evidence/capacity building are necessary. Market incentives and an increase in the ease of doing business may be crucial. A concerted and coordinated effort by private and public sector as well as farmer organisations is needed. We conclude with policy recommendations for the different actors along the fertiliser value chains.

The impacts of groundwater development on agriculture food system in Senegal: A general equilibrium assessment

Angga Pradesha, Hua Xie, James Thurlow, Claudia Ringler

International Food Policy Research Institute (IFPRI), United States

Most country in sub-Saharan Africa, including Senegal mainly rely on rainfed system for the agricultural production that provides sub-optimal productivity level compared to the irrigated production system. This condition has led to food and economic insecurity given variability in agriculture production that inhibits the poor from improving their livelihoods. On the other hand, there is huge potential of groundwater resources in the region that could potentially help improve agricultural production through groundwater irrigation. This study examines the potential impact of groundwater in Senegal by using Rural Investment and Policy Analysis Water (RIAPA-W) model to understand how groundwater development across different regions in the country shape agricultural food system and how it affects income distribution, poverty, and food security in year 2030. Simulation results show that increasing water supply by around 20 percent through groundwater development in 2030 would increase agricultural production in both crops and livestock sectors. This spur on production leads to an increase in agriculture and national GDP by 3.4 and 1.5 percent respectively. The simulation results also capture the spillover effect on non-farm food system where larger economic impact shown in food service sector, while higher employment effects observed in food processing industry. Income distribution shows that both rural and urban poor are gaining more than the non-poor household despite all household generated higher income under new groundwater development. As income increases across different households, especially the poor, we found poverty is reduced by around two hundred thousand people in 2030. Increase in groundwater supply also helps provide clean water which is estimated around three hundred thousand people have access to clean water.

Keywords: Agriculture and food system, general equilibrium, groundwater

Contact Address: Angga Pradesha, International Food Policy Research Institute, Foresight and Policy Modeling, 1201 eye st nw, 20005 Washington, United States, e-mail: a.pradesha@cgiar.org

Value chain development of a clean-burning solid biofuel in Southern Africa

Joshua Aseto, Kartika Anggraeni, Adriana Ballon Ossio

Collaborating Centre on Sustainable Consumption and Production (CSCP), Sustainable Business and Entrepreneurship (SBE), Germany

Bush encroachment degrades over 120 million ha across Southern Africa. It stifles herbaceous plants, reduces biodiversity, depletes groundwater reserves, and degrades the soil. Its negative ecosystem impact undermines surrounding communities' food and water security. Encroachment diminishes and weakens productive farmlands and rangelands, reducing livestock productivity. Encroached areas can lose over 44 million litres/year/ha of groundwater through evapotranspiration. This threatens the fragile water balance in these semi-arid regions. However, the costs of controlling the bush encroachment exceed the immediate benefits of increased agricultural productivity. There is a pressing need to create value for the harvested biomass (bush). The EU Horizon 2020 "SteamBioAfrica" project seeks to create added value through the use of superheated steam (SHS) technology with an output of a clean-burning, solid biofuel for household as well as industrial consumption in three target countries of Botswana, Namibia and South Africa. As part of the project, the CSCP together with partners are developing value chains for the solid biofuel, which eventually will contribute to enhancing the renewable energy sector of the three countries. In 2022, the project undertook a baseline survey to gain insights into the existing biomass value chains. The value chain analysis employed a mix of qualitative and quantitative data analysis, which included a baseline survey, key informant interviews, and literature reviews. Collected qualitative data went through a triangulation process and collected quantitative raw data went through frequency analysis for the categorical variables for each country. Collected data was compiled and contrasted. Conclusions were then reached through logical inference based on a set of observations and seeking the most likely and simplest inference from the observations. The findings reveal, households in the three countries still use a mix of energy sources for cooking and heating. These include firewood, LPG, paraffin and electricity. More than 50 % of respondents reported using firewood, particularly in rural areas, while charcoal is generally used for leisure activities such as "braai" (barbecue) due to its higher price than firewood. Introducing the new solid biofuel to households will require new business models.

Keywords: Agricultural productivity, biodiversity, biomass value chains, bush encroachment, business models, farmlands, solid biofuel, SteamBioAfrica, superheated steam (SHS) technology, water security

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Contact Address: Joshua Aseto, Collaborating Centre on Sustainable Consumption and Production (CSCP), Sustainable Business and Entrepreneurship (SBE), Hagenauer Str. 30, 42107 Wuppertal, Germany, e-mail: joshua.aseto@cscp.org

Importance and effectiveness of waste decomposer in biodegradable and agro-waste management in context of Nepal

Sabina Devkota[1], Geeta Bhatrai Bastakoti[2], Shree Vista[1]

[1]*Nepal Agricultural Research Council, National Soil Science Research Center, Nepal*
[2]*Community of Evaluators, Nepal (CoE-Nepal), Nepal*

Solid waste is byproduct of human activities which tends to increase with rapid urbanisation, improved living standards and changing consumption patterns. If solid waste is properly used, it can be a valuable resource, but if it is not effectively managed, it can result in serious adverse impacts on environment and public health. The waste i.e. kitchen waste, and other biodegradable waste which can be useful to make a compost. Agro waste management in Nepal remains an important issue which still needs to be given more importance considering its policy gaps and management mechanism. Kathmandu Metropolitan city has focused on bio waste management in their annual policy and programme (2018/2019) but management ways are still unclear. Many farmers using different types of waste decomposers buying from the market to decompose the waste and to utilise it later as a fertiliser. Despite its promotion there remains a less understanding of how this bio decomposers are being promoted by the actors involved in the value chain. In this context, waste decomposers may be the option to decompose bio-waste materials quickly. Incomplete or immature composts cause many deleterious effects to soil, which in turn affects plant growth and ecosystem function. This study basically tries to understand what kind of waste decomposers are available in the market Nepal, what range of composition is being preferred by the users and the results of satisfaction by the users in terms of waste decomposer. Linking the findings with policy, this paper explores and identifies the gaps in terms of waste decomposers that policy can address and the areas that need to be addressed and considered for improvement at institution level for effective waste management.

Keywords: Waste, waste decomposer, waste management

Contact Address: Sabina Devkota, Nepal Agricultural Research Council, National Soil Science Research Center, Bhaisepati, Lalitpur, Nepal, e-mail: sabina.devkota@gmail.com

Innovative integration of renewable energy and agricultural production as contribution on sustainable local development

Osvaldo Romero Romero, Michael Hartmann, Katia Caraballoso Granado, Matthias Raab

SRH Berlin University of Applied Science, Berlin School of Technology, Germany

Humanity is struggling to face problems associated with development related to climate change, finite energy resources, food scarcity, waste production and management, as well as water availability and contamination. Simultaneously, population growth, rising living standards and technological-industrial development have an undeniable effect on increasing food and energy consumption, with an impact on the over-exploitation of essential natural resources such as water and soil. At the same time, rural communities in most developing countries have limited access to products and services that are commonly used in cities, such as energy, health, and cultural life, among others, which unbalances their development and sustainability.

In the international discourse and the increase in awareness of these problems, the implementation of the SDGs and concepts such as the green economy, the water energy food nexus, the circular economy, the development of renewable energies are promoted. However, in a society that forecasts more than 9 billion inhabitants by 2050 and demands increased by 60 % for food, 55 % for water and 80 % for energy, close to one billion people still suffer from hunger, 78 % of the world population must be satisfied with only 30 % of the energy produced globally, 2.12 billion tons of waste are produced annually and 1.2 billion people face physical water scarcity, while food still has to be transported nearly 4000 km as average from producer to consumer; even so renewable energy generation and food production must compete for the land resource.

The present work will present theoretical-practical reflections of the innovative integration and management of renewable energies with agro-productive systems, to achieve synergies that allow increasing food and energy production with sustainable strategies, contributing to local development and reducing gaps in living standards in rural regions of developing countries. Possible configurations to consider in pilot examples, unifying knowledge in training and profession of engineers are presented, promoting sustainable rural communities to impulse SDGs, growing in a green economy, managing the water-energy-food-nexus, and in a circular economy, as well as decentralising food production with an economic impact on the inhabitants of rural communities, and on regional-national economies.

Keywords: Circular economy, green economy, integration renewable energy and food production, rural local development, SDGs, water-energy-food-nexus

Contact Address: Osvaldo Romero Romero, SRH Berlin University of Applied Science, Berlin School of Technology, Ernst Reuter Platz 10, 10587 Berlin, Germany, e-mail: osvaldo.romero@srh.de

Effectiveness of improved cookstoves in promoting sustainable food consumption: A case study of a rural community in Meghalaya, India

Subha Niranjan

Infosys Ltd, Subha Niranjan, India

Unsustainable food consumption practices have contributed to environmental degradation and exacerbated climate change, particularly in vulnerable communities. This case study examines the effectiveness of a carbon offset project by Infosys, which supplied approximately 10,000 improved cookstoves to families in rural Meghalaya, India. The project aimed to reduce greenhouse gas emissions, promote sustainable consumption and production, and improve the quality of life of the rural community. The project positively impacts 11 of the 17 SDG goals.

Through this study, we explore the impact of improved cookstoves on sustainable food consumption, with a focus on the reduction of firewood usage and associated deforestation. Additionally, we examine the effect of the project on poverty reduction, health, and women's empowerment. Our methodology includes both qualitative and quantitative data collection methods, including surveys and interviews with project participants.

Preliminary findings indicate that the project has had a positive impact on sustainable food consumption and the community's overall well-being. Improved cookstoves have reduced the use of firewood and associated deforestation, as well as improved indoor air quality, reducing health risks associated with traditional cooking methods. Additionally, the time saved in cooking and wood collection has allowed for more income-generating activities and household tasks.

Our study highlights best practices and lessons learned from the project and identifies potential areas for further research and innovation in promoting sustainable consumption and production. By contributing to the body of knowledge on sustainable food systems, this study can inform future projects aiming to improve the well-being of rural communities and reduce the environmental impact of food consumption practices.

Keywords: Livelihood improvement, reduce GHG emissions, sustainable consumption and production

Contact Address: Subha Niranjan, Infosys Ltd, Subha Niranjan, 1014 sobha suncrest sobha hillview off kanakapura road, 560062 Bangalore, India, e-mail: subhaniranjan@gmail.com

Sustainable energy access: A catalyst to landscape restoration and water management in rural Malawi

Lameck Nkhonjera[1], Annie Thokozani Mpeketula[2]

[1]*Wupla Enterprise, Sustainable Energy, Malawi*
[2]*Catholic University of Malawi, Development Studies, Malawi*

The high increase in population over the past two decades in Malawi has contributed to environmental degradation. Out of about 20 million Malawians, 82 % live in rural areas. They depend on subsistence agriculture for a living, whereas firewood and charcoal are predominantly used for cooking. The source of water for domestic use is from wells (protected and unprotected) and surface water. The clearing of land for cultivation as well as unsustainable harvesting of biomass for cooking are the main contributors to land degradation. Can increased access to sustainable energy in rural Malawi accelerate landscape restoration and increased agricultural productivity? Through a literature survey, this study argues that energy poverty is one of the salient drivers of the perceptible environmental degradation in Malawi. With access to modern energy, the economic activities in the rural areas can increase and thus uplifting low income levels of the rural populace and hence enabling them to become good stewards of the natural resources around them. With access to sustainable energy, information and knowledge sharing of the environmental issues in the rural communities can be eased, thus assisting in behavioural change of those who unknowingly cause harm to the environment. With access to energy, smart agriculture in the rural areas is possible and thereby reducing pressure on search for cultivation land as adequate yields can be obtained from the small piece of land. With access to energy, efficient water management is possible. It is therefore concluded that integrating energy access in the landscape restoration and water management programmes in rural Malawi has far reaching impacts.

Keywords: Landscape restoration, sustainable energy, water management

Contact Address: Lameck Nkhonjera, Wupla Enterprise, Sustainable Energy, Off S137 road, Golowa Village, T/A Kuntaja, Chileka , 311105 Blantyre, Malawi, e-mail: lameck.nkhonjera@wupla.org

Coproducing the water-energy-food-biodiversity nexus to operationalise agri-food systems sustainability transitions

Diana Cristina Moreno Vargas[1], Carolina del Pilar Quiñones Hoyos[2],
Olga Lucía Hernández - Manrique [3]

[1]*National University of Colombia, Humboldt Research Institute: Trajects, Colombia*
[2]*World Bank Group, Environmental Psychology Node of Ascofapsi, Colombia*
[3]*Basque Center for Climate Change, Adaptation Lab, Spain*

Rising resource scarcity and environmental conflicts over water, energy, and food, coupled with population growth and climate change, pose a severe threat to biodiversity conservation and culture. The Water-Energy-Food nexus and coproduction are prominent solutions to elucidate these threats. On the one hand, this contribution aims to fill the gaps identified in the nexus thinking by integrating the Water-Energy-Food and Biodiversity elements into a single framework. On the other hand, we attempt to summarise the nexus research focused on social-ecological transitions in agricultural systems and biodiversity management within the Water-Energy-Food nexus. Through a systematic review and a bibliometric analysis applying the VOS visualisation tool and ToS methods, we aimed to elucidate this information from 529 documents in the Scopus database. We identified through the ToS method 81 relevant information in the documents´ sample (529) categorised into roots (10), trunks (9), and leaves (62). Our research situates types, focus, and highlights regarding biodiversity and prevalent thematic research areas such as environmental flows, food nexus, sustainability, transitions, and governance. Our results suggest that future research should focus on the nexus of Water-Energy-Food-Biodiversity and could pose a interdisciplinary approach with some implications not only in the use of resources but also in the scenarios, scales, indicators, and long-term interactions, and situates demands of biodiversity conservation which can be supplied or balanced by agri-food systems at landscape levels. Strengthening different knowledge networks through a coproducing roadmap would contribute to public policy generation in scenarios of sustainability transitions in agri-food systems. This framework could increase stakeholder interest in conservation, and sustainability management, to reverse biodiversity losses in ecosystems.

Keywords: Biodiversity conservation, environmental flows, governance, sustainability transitions, water-energy-food nexus

Contact Address: Diana Cristina Moreno Vargas, National University of Colombia, Humboldt Research Institute: Trajects, Cra 16 C N 160 - 39, 111321 Bogotá d.c, Colombia, e-mail: dcmorenov@unal.edu.co

Technology suitability maps for bioenergy potential in Togo

Friederike Naegeli de Torres[1], Fabian-Constantin Sittaro[1], Sebastian Semella[1], Jérémie Fontodji[2], Tcha Thom Maglwa[3], Edem Koledzi[3], Nils Engler[1], Komi Agboka[3]

[1]*German Biomass Research Center (DBFZ), Germany*
[2]*University of Lomé, Laboratory of Forest Research, Togo*
[3]*University of Lomé, Laboratory of Waste Management, Treatment and Recovery (Laboratory GTVD), Togo*

Energy transition in Togo is crucial to counteract deforestation and the effects of climate change. The production of bioenergy from agricultural residues and household waste offers a promising solution, but the identification of suitable regions, residues and technologies can be challenging due to a lack of data availability. Here, we present an approach to assess the regional bioenergy potential in Togo by calculating the technology specific input amount and the spatial availability of substrate for bioenergy applications based on categorised agricultural residues and household waste. We analyse the chemical components of agricultural residues from different crops and conducted feasibility tests to categorise them based on their suitability for biogas or pyrolysis. Spatially disaggregated crop production data from the International Food Policy Research Institute (IFPRI), crop-to-residue ratios and household waste data are then used to identify and locate the available residual biomass. We use resampling algorithms, focal statistics and technical parameters of bioenergy facilities to calculate the amount of substrates available for bioenergy production on a regional and local scale. We further calculate the biogas potential of major poultry farms in Togo, based on the potential manure quantities and the agricultural residues in vicinity to the farm. The regional suitability for bioenergy applications depends on the category of residues but is generally greater in southern Togo. All suitability analyses can easily be adapted by changing the values of the underlying assumptions. It is therefore planned to extend the models as an interactive web tool where users can directly adjust the values of the underlying parameters (e.g. residue collection rate, plant size). Overall, our approach provides valuable insights into the regional bioenergy potential in Togo and can inform policy decisions to promote sustainable development. By using chemical component analyses and crop production data, we were able to identify suitable regions and residues for bioenergy applications and calculate the availability of substrate for biogas or pyrolysis production.

Keywords: Bioenergy, crop production data, GIS, technology suitability maps, Togo

Contact Address: Friederike Naegeli de Torres, German Biomass Research Center (DBFZ), Bioenergy Systems, Torgauer Str. 116, 04347 Leipzig, Germany, e-mail: friederike.naegeli@dbfz.de

Evaluation of waste management in southwestern Nigeria for clean environment, circular economy and agri-food systems development

Opeyemi Anthony Amusan

University of Ibadan, Amiesol Resources Konsult / ERK Energy GmbH, University of Ghana Business School, Nigeria

Poor waste management results in environmental, ecological and socioeconomic problems in Southwestern-Nigeria. Attempts at managing waste through burning can lead to climate change while landfill leachate reduces soil and ground water quality. Hence, the need to look for better alternative. This research looks at the current challenges in the waste management system in Southwestern-Nigeria and proposes a more contemporary system that will move the region towards attaining a circular economy. Environmental Kuznets Curve hypothesis provided theoretical framework. Purposive sampling of major landfills in Lagos, Ogun, Oyo, Osun, Ondo, Ekiti States and waste generation pattern using structured questionnaires (210) on spatial variation, challenges and prospect of waste management practices. The results were validated at expert workshop for key officials within the waste management industry(30). Data were analysed using descriptive and inferential statistics. Waste Habits of Nigerians were 57.0 % organic/food-waste, 27.0 % plastics, 5.0 % glass, 5.0 % metal and 4.0 % others, ending up mostly on landfills/dumpsites. Only 28.1 % separated waste at source and 46.2 % used private collection services. The major waste management challenges were pollution and health risks (69.1 %), limited resources(44.8 %), lack of technical skill(23.8 %) and inadequate management skill(18.1 %). As part of waste management practices, 95.2 % were willing to participate in circular economy, 94.3 % supported polluter pays principle and 96.2 % supported dissemination of public information on Waste-to-Energy. Waste management challenges significantly influenced health issues and pollution ($p = 0.048$). From the current linear economy to circular economy, there is a need for a paradigm shift in the product economy regarding the curtailing of environmental impact and waste-of-resources through increased efficiency at all stages. With a circular economy, waste is seen as a viable resource and not an undesirable end product of society. Waste is seen as input material for the creation of valuable products as new outputs for agri-food systems development. For this to be successful, all hands must be on deck and all stakeholders actively involved. There must be seamless synergy in the products development, infrastructure, equipment and services sector with the conventional waste managers rightly supported to take the driver's seat. The government has a role in creating an enabling environment and stimulating demand.

Keywords: Agri-food system, circular economy, clean environment, waste habits, waste management challenges

Contact Address: Opeyemi Anthony Amusan, University of Ibadan, Amiesol Resources Konsult / ERK Energy GmbH, University of Ghana Business School, P.O. Box 23039, 200013 Ibadan, Nigeria, e-mail: amusanopeyemi@yahoo.com

Potential water harvesting sites for groundwater recharging using remote sensing and GIS for modern irrigation scheme

Mohammed Ismail Adam[1], Abdalla Gumaa Farwa[2], Jamal Marda Abdo[2]

[1]*Ministry of Water Resources, Irrigation and Electricity, Sudan*
[2]*Khartoum University, Sudan*

Groundwater uses for modern irrigation purposes is a new trend in different countries in the world nowadays. The use of groundwater for these purposes normally is linked with different problems especially when it is over-extracted. Third-world countries are suffering lack of clean water compared to developed ones. In addition to that many conflicts around the world happen because of water resources. Moreover, due to climate change the problem will extend in the future, therefore more efforts are needed from international organisations. The high climatic variation prone to unreliable rainy seasons leads to droughts and desertification. Besides climatic, the poor policies help in the deterioration of water resources. Shortage of drinking water for human activity, livestock, and irrigation is a mean problem in different regions of Sudan. So the collection of rainfall water is one important water resource management in Sudan. This was achieved by designing and constructing small dams, Hafirs, and groundwater wells to solve the problems. During the last decade space-borne and airborne remote sensing technologies with geographic information systems (GIS) are widely used in water resources management. Nowadays satellite remote sensing has the possibility to provide wide coverage of variables such as precipitation, land cover, digital elevation, soil moisture, and vegetation change that are important inputs to modern hydrological models. The combination of surface and subsurface data in the decision support matrix to achieve the best site selection is used. In weighted overlay analysis rank values are assigned for each class of all thematic data layers according to their influence on groundwater recharge and factor-weighted values are assigned. Finally, the accuracy of sites being determined in GIS Software by field check verification shows that GIS is power full, cheap, and simple tool for quick decision take.

Keywords: Artificial recharge, GIS, remote sensing, salt-water/fresh-water relations, Sudan, water supply

Contact Address: Mohammed Ismail Adam, Ministry of Water Resources, Irrigation and Electricity, Nile street, 1111 Khartoum, Sudan, e-mail: adam_ahamed2001@yahoo.com

An analysis of the cost-effectiveness of solar-powered irrigation systems in Côte d'Ivoire

Natascha Scarff[1], Götz Uckert[2], Johannes Muntau[3], Michel Peudré Digbeu[3], Stefan Sieber[2]

[1]*Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Switzerland*

[2]*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany*

[3]*German Agency for International Cooperation GmbH (GIZ), Water and Energy for Food (WE4F), Côte d'Ivoire*

Food insecurity, malnutrition, and poverty remain pervasive problems in Côte d'Ivoire (CI). Improving agricultural productivity through irrigation development is considered a potential solution to help address these challenges, however, this approach requires energy. Solar-powered irrigation systems (SPISs) have gained global attention as a clean energy solution for irrigation. Nonetheless, the adoption of SPISs in CI is contingent on their cost-effectiveness in comparison to conventional irrigation systems powered by traditional energy sources. This study assessed the cost-effectiveness of a small-scale SPIS relative to a comparable diesel-powered irrigation system (DPIS) for a single case in Gbandokaha, northern CI, using crop and site-specific input data for requirements under semi-arid conditions. Using a modelling approach, only the anticipated cost differences between the SPIS and the DPIS were estimated and compared. The analysis included financial life-cycle costs (LCCs) as well as environmental LCCs from carbon dioxide (CO_2) emissions. LCC estimates were informed by sizing the power units of both irrigation systems for groundwater pumping for dry season irrigation of eggplant crops on a 1 ha field. The analysis considered a 25-year assessment period with varying annual diesel fuel price escalation rates (0 %, 2 %, and 4 %) and a discount rate of 4.38 %. The study found that the initial capital cost of the DPIS is only 54.8 % of that of the SPIS. However, the lifetime maintenance and operation costs, as well as the total LCCs of the SPIS, are significantly lower than those of the DPIS, accounting for only 1.4–2.1 % and 13.2–19.1 %, respectively. The payback periods for the SPIS to achieve the same total LCCs as those of the DPIS were estimated to be 1.4 years. Moreover, the results showed that the primary cost component of the SPIS's total LCCs is the initial capital cost (89.8 %), while for the DPIS, it is the lifetime diesel fuel cost (84.9–89.6 %). Additionally, the study revealed that adopting the SPIS could reduce lifetime CO_2 emissions by 99 % compared to the DPIS. The findings of this study offer insights into promoting solar irrigation and its implications for the development of low-carbon emission irrigated agriculture in CI.

Keywords: Cost comparison, cost-effectiveness, Côte d'Ivoire, diesel irrigation, groundwater irrigation, photovoltaic irrigation, solar irrigation, solar-powered irrigation systems

Contact Address: Natascha Scarff, Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Geneva, Switzerland, e-mail: natascha.scarff@gmail.com

Multicriteria analysis to operationalize agri-food systems sustainability transitions in the water-energy-food-biodiversity nexus

Jeimy Andrea García García[1], Leidy Tatiana Silva Ruíz[1],
Diana Cristina Moreno Vargas[2]

[1]*Alexander von Humboldt Biological Resources Research Institute, Colombia, Nature-Based solutions thinking center, Colombia*
[2]*National University of Colombia, Humboldt Research Institute: Trajects, Colombia*

Agroecological efficiency in natural resources use and access equally conservation and enhancement of supporting, regulating, and cultural ecosystem services have been identified as central challenges for agri-food systems. Multicriteria spatial analysis and land use zoning processes are valuable tools to address these challenges. This study aims to prioritise crucial areas in agricultural use at the Chingaza paramo complex in Colombia with opportunities for sustainability transitions. Three methodological phases were developed through a multicriteria spatial analysis using the ArcGIS Pro software and Corine Land Cover methodology in 2022 based on available cartographic information in Colombia: (i) Landscapes prioritisation based on criteria identification (n=11), (ii) Development of a baseline concerning multifunctionality categories in the prioritised landscapes (n=5), (iii) Selection and valuation of areas in agri-food systems sustainability transitions expressed in land cover at a scale of 1:25,000, applying exclusion (n=4), and valuation areas criteria (n=6). Our research situates the Siecha River micro-basin area (2068.16 ha) with Orobioma andino and Paramo Altoandino eastern mountain range ecosystem units and highlights an intermediate human footprint index, the areas associated with potential agricultural activities (1.31 %), heterogeneous agricultural uses (11 %), and small-scale agriculture (10 %) with moderate (7.81 %) and severe (3.33 %) land overuse. Medium (18.17 %), low (17.07 %), and very low (16.5 %) sustainability categories stand out in the areas related to the provision of agri-food products. Our results suggest that lower-value areas present opportunities for sustainable transitions through nature-based solutions that promote recovered productive capacity and improve fertility and soil stability, and water regulation. Areas with higher valuations also present a great potential to make visible and replicate processes and practices that offer better opportunities for landscape sustainability. Besides, it is necessary to understand crucial variables for sustainable transitions, nexus, and exchanges within the areas highly associated with biodi-

Contact Address: Jeimy Andrea García García, Alexander von Humboldt Biological Resources Research Institute, Colombia, Nature-Based solutions thinking center, Circunvalar avenue N 16 - 20, 110321 Bogotá d.c., Colombia, e-mail: andreag321@gmail.com

versity management, protection, and conservation. Strengthening different nexus knowledge of uses in areas with similar conditions would contribute to public policy generation in scenarios of sustainability transitions in agri-food systems. This framework could promote specific metrics for spatial hierarchy in agri-food systems sustainability transitions in the Water Energy-Food-Biodiversity nexus.

Unlocking the potential of biogas technology in West Java, Indonesia: A multilevel analysis of adoption barriers and opportunities

RICARDO SITUMEANG, JANA MAZANCOVÁ, HYNEK ROUBIK

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic

A viable method for producing sustainable energy, particularly in developing country, is biogas technology. However, the use of biogas technology has only been partially adopted in places like West Java, Indonesia. This study used a multilevel analysis that took into account the levels of the individual, organisation, and institution to determine the factors impacting the adoption of biogas technology in West Java. This study used a mixed-method approach that included interviews with significant stakeholders and a survey of 208 farmers. The findings suggested that a lack of technical expertise and financial resources, as well as insufficient assistance from the government and other organisations, were the main obstacles to the implementation of biogas technology. Particularly, the farmers lacked the technical know-how and abilities needed to set up and maintain biogas technology. Despite the obstacles, this study identified several opportunities for the uptake of biogas technology in West Java, including the potential for income generation, health benefits, and environmental sustainability. Biogas technology can provide farmers with a dependable source of energy and fertiliser, minimising their reliance on fossil fuels and chemical fertilisers. Furthermore, the use of biogas technology can help mitigate the negative impact of agriculture on the environment by reducing greenhouse gas emissions and enhancing soil health.The study suggests a comprehensive approach to overcome the barriers to the adoption of biogas technology in West Java, which involves improving technical skills and knowledge through training programs, increasing financial support through grants and subsidies, and enhancing government and organisational support through policies and regulations

Keywords: Adoption, biogas, rural development, sustainability

Contact Address: Ricardo Situmeang, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Kamýcká 129, 16500 Prague, Czech Republic, e-mail: situmeang@ftz.czu.cz

ID 510

Towards harmonisation of biogas research: A comprehensive systematic review of anaerobic digestion parameters and processes

Antoine Bercy, Hynek Roubík

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Czech Republic

Anaerobic digestion is an important renewable energy technology that has the potential to reduce greenhouse gas emissions and contribute to the development of a sustainable energy system. However, research on anaerobic digestion is extensive and fragmented, making it difficult to gain a comprehensive understanding of the technology. Therefore, this systematic review, based on the PRISMA protocol, aims to provide a comprehensive overview of the anaerobic digestion process, from pretreatment to gas utilisation, and the research conducted in each step. The review involved analysing 4745 articles and identified the following research parameters: pre-treatment (1291), reactor design (949), temperature (918), H_2S cleaning (894), and biogas upgrading (693). These parameters were chosen as they are requirement to conduct anaerobic digestion and need to be planned and cannot really be changed during process, like, for example, mixing regime can. For each parameter, the review identified in each article the processes used. This information will serve as a basis for future standardisation of work to increase the efficiency of biogas research. It is important to note that the objective of this review is not to provide an analysis of the benefits or drawbacks of each listed method. This information should be covered in specific systematic reviews. However, this review will facilitate the identification of knowledge gaps or new innovative research. This research can help gain a better understanding of technology in general and help new researchers understand the field. This also highlights the urgent need for harmonisation of research to facilitate knowledge transfer and avoid redundant work or the overlooking of potential breakthrough research, while also indicating to researchers where focus should be orientated. A better harmonisation can help automatise research findings to compare results faster while avoiding tedious and long review work.

Keywords: Biogas technology, PRISMA protocol, research harmonisation, systematic review

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Contact Address: Antoine Bercy, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Sustainable Technologies, Kamýcká 129 165 00, 16000 Praha, Czech Republic, e-mail: bercy@ftz.czu.cz

Institutions

Advancing a demand-driven research portfolio to improve water, land and food systems in the Global South (CGIAR/Systems Transformation Action Area)

The role of groundwater as an accelerator of agricultural transformation: Insights from the CGIAR initiative on NEXUS Gains

Claudia Ringler, Hua Xie, Ruth Meinzen-Dick, Nicos Perez

International Food Policy Research Institute (IFPRI), United States

The CGIAR Initiative on NEXUS Gains works at the critical intersection of food, energy, and water security while preserving the environmental systems underlying food systems in selected transboundary river basins. Among natural resources, groundwater has become increasingly critical to water, energy and food security, climate resilience and overall environmental sustainability. In many low-and middle-income countries, groundwater development is also essential for agricultural and economic growth.

Accelerated groundwater development is particularly needed in Sub-Saharan Africa where climate variability severely affects farmers' livelihoods and national food security. At the same time, groundwater development has led to substantial depletion and degradation of natural resources in key breadbasket areas of the world. This presentation covers three strands of research on groundwater that NEXUS Gains and partners are pursuing: 1) What are tradeoffs between maintaining renewable groundwater systems and global food security and how can we reduce the costs of these tradeoffs? 2) What is the potential of groundwater development for economic growth and poverty alleviation in areas where development and tradeoffs are more limited? And 3) What institutions can support groundwater governance to reduce groundwater depletion and degradation?

Our results suggest that groundwater use will continue to grow, particularly for irrigation, fueled by cheaper solar pumps that are becoming more widely available. Increased groundwater irrigation is key to agricultural and economic development in a climate crisis, particularly in Sub-Saharan Africa. There is a strong tradeoff between food security and more sustainable groundwater development. Several options can reduce the costs of these impacts, such as improving water management in rainfed areas, investing in agricultural R&D, or adjusting diets. More effective measures on dealing with depletion are starting to be developed but are unlikely to affect depletion in the near- to medium term.

Keywords: Food security, governance, groundwater, irrigation

Leveraging agroecological transitions: Experiences from the CGIAR initiative on agroecology

Marcela Quintero[1], Veronique Alary[2,4], Sarah Freed[3], Aymen Frija[4], Lisa Fuchs[5], Sarah Jones[1], Christine Lamanna[5], Guillermo Orjuela[1], Simone Staiger[1], Claudia Tristan[1]

[1]*The Alliance of Bioversity International and CIAT, Colombia*

[2]*SELMET, CIRAD, INRAE, Institut Agro, Université Montpellier, France*

[3]*World Fish, Cambodia*

[4]*International Center for Agricultural Research in the Dry Areas (ICARDA), Tunisia*

[5]*Center for International Forestry Research-World Agroforestry (CIFOR-ICRAF), Kenya*

Agroecology is defined by a set of principles that can enhance food system resilience, equity, and sustainability. These principles imply changes in the way food is produced, how farmers are connected to the rest of the food system, and how food reaches consumers.

The CGIAR Initiative on Agroecology works in "Agroecological Living Landscapes" (ALLs), where diverse food system actors are convened to work towards commonly agreed agroecological transition pathways with focus on: i) evidence building, assessing what agroecological innovations work best, where, why, and for whom, ii) agroecological business opportunities and financial mechanisms for local enterprises, iii) strategies and action plans that encourage, and support behavior change oriented to agroecology, and iv) suitable agroecological policies and policy integrations.

Examples from three countries showcase how systemic and participatory approaches in ALLs support different agroecological transitions:

Kenya: The ALLs, located in the Murang'a / Machakos corridor are related to the advancement of sustainable production systems including practices such as plant-based biopesticides, farmyard manure, terraces, water harvesting and agroforestry. The transition pathway includes strengthening farmers' networks and connectivity to markets, and the creation of inclusive business models in prioritized value chains (mango and green leafy vegetables). This work is connected to country-level efforts led by the Inter Sectoral Forum on Agroecology and Agrobiodiversity (ISFAA) to develop a national agroecology policy.

Tunisia: The transition pathway focuses on various production systems that interplay in the ALL situated in the transect El Kef-Siliana: Crop-livestock, olive agroforestry, and honey and carobs systems. Innovations aim at crop diversification and rotation, feed management to cope with forage scarcity during dry periods, input reduction, and recycling, coupled with business

Contact Address: Marcela Quintero, The Alliance of Bioversity International and CIAT, Km 17 Recta Cali-Palmira, 763537 Cali, Colombia, e-mail: m.quintero@cgiar.org

model improvements (I.e., valorizing the Tunisian olive oil in the market). Like Kenya, the initiative supports the development of a national strategy, in this case for crop-livestock systems.

Peru: The focus of the ALL located in Ucayali is to enhance the sustainable production of organic cocoa systems including agricultural diversification of smallholders faming, increased inclusivity of the current business models, and scaling the approach in the region with greater support from policy makers and investors. In support of the transition, ALL actors agreed to explore carbon markets as a complementary financial strategy for the transition.

The initiative developed and now applies a Holistic Localized Performance Assessment Framework comparing the status of agroecological principles across contexts and setting a baseline for monitoring progress. Studies of past agroecological initiatives in the ALL regions distil the key determinants for behavioural change.

Keywords: Agroecology, agroecological transitions, Global South

Applying a social equity approach to transformative adaptation: Minimising trade-offs between environmental and socio-economic outcomes

Ana Maria Loboguerrero[1], Jon Hellin[2], Sabrina Rose[3]

[1]*The Alliance of Bioversity International and CIAT, Italy*
[2]*International Rice Research Institute, Sustainable Impact, Philippines*
[3]*The Alliance of Bioversity International and CIAT, Colombia*

Droughts, erratic rainfall, floods and high temperatures threaten the livelihoods of millions of smallholder farmers. Significant effort has focused on climate risk management, including the promotion of climate-resilient agriculture, directed at particularly vulnerable people and areas. Innovative technological interventions are critical but the enabling social, institutional and governance environment drives the transformative process. Climate risk management may, however, result in trade-offs between environmental and socioeconomic outcomes. An example is 'maladaptation' whereby interventions (inadvertently) create, redistribute and/or reinforce inequality and vulnerability. Maladaptation is at odds with 'leave no one behind'. This brings to the fore social equity that relates to responsibility for and distribution of climate impacts and policies across society, generations and genders, including in terms of who participates in and controls decision-making.

Adopting a social equity approach enables agricultural researchers to consider how social difference and associated inequalities, including gender, may shape vulnerability and may influence people's access to innovations to build resilient and improved livelihoods. It, hence, contributes a deliberative transformation to just, equitable and resilient food systems. We illustrate this with examples from i) climate finance, ii) policy pathways and iii) climate information services. Farmer adoption of climate-resilient agriculture is stymied by risk and farmers' risk aversion. We report on Risk-Contingent Credit (RCC), a linked financial product that embeds within its structure an insurance protection which, when triggered, offsets loan payments due to the lender. RCC mitigates drought-related agricultural risks and provides access to credit for smallholder farmers, requiring minimal collateral.

Policy pathways research combines future scenarios (based on integrated modelling of the agriculture sector) with expert input on relevant policy objectives. The latter is designed to ensure that key stakeholder groups, whose voices may not be readily heard in policy settings, are active participants in discussions around integrated modelling. Lastly, The Zambia Drought Management System (ZADMS) is a satellite-based online resource that provides farmers, extension workers, and agriculture and water resources authorities the information needed to forecast, monitor, and manage drought. It provides (sub)seasonal and seven-day weather forecasts; monitoring tools to indicate when drought is present; and district-level agricultural contingency plans.

Keywords: Climate change, gender, resilience, social equity, trade-offs

Navigating climate mitigation in global food systems: Insights from CGIAR

Mary Eyeniyeh Ngaiwi, Nicolas Hoyos, Robert Andrade, Maria del Mar Esponda, Eliza Villarino, Augusto Castro-Nunez

The Alliance of Bioversity International and CIAT, Colombia

Food systems provide critical food and nutritional security, livelihoods, and socio-economic benefits, as well as negative externalities such as emissions from the land use change sector. The new IPCC report makes grim reading, and the urgency for accelerated climate mitigation has never been clearer. Increasingly, the US$12 trillion global food system is in the spotlight, contributing 21–37 % of global greenhouse gas (GHG) emissions (72 % of which from the Global South). The substantial share of GHG emissions attributed to the global food system, alongside its adverse impacts on food production, hunger, and poverty, underscores the pressing need for identifying viable pathways for catalyzing transformative changes in food systems. The Paris Agreement (PA) target of limiting global temperature increases to 1.5°C was a critical milestone in catalyzing systems change. The commitment of all nations, including Paris Agreement's signatories from the Global South, to reduce greenhouse gas emissions highlights the importance of collaborative efforts, especially in sectors like agriculture and food systems. In such context, this presentation aims at shedding light on the extent of CGIAR's role in driving low emissions transformative change within the global food system. Specifically, we analyse CGIAR research publications, innovations, and current portfolio of initiatives to critically assess its contributions to climate change mitigation and low emissions development. Special attention is directed towards CGIAR's Research Initiative on Low-Emission Food Systems, Mitigate+. This initiative aligns with the evolving global climate change frameworks, moving away from the Kyoto Protocol's differentiated mitigation commitments, wherein only developed countries were mandated to reduce emissions, towards the more universally applicable approach of the Paris Agreement, which urges global response to climate change in the context of sustainable development and poverty eradication.

Keywords: CGIAR, climate change mitigation, low emissions food system, low-emissions development

Responsible digital innovation in agri-food systems: Ethical and equitable transformation for sustainable agriculture

Jawoo Koo[1], Andrea Gardeazabal[2], Jonathan Steinke[3]

[1]*International Food Policy Research Institute (IFPRI), United States*
[2]*International Maize and Wheat Improvement Center (CIMMYT), Mexico*
[3]*The Alliance of Bioversity International and CIAT, Digital Inclusion, Italy*

Responsible digital innovation in agri-food systems refers to the ethical and sustainable development, implementation, and use of digital technologies to enhance agriculture and food production while considering the well-being of farmers, consumers, the environment, and society as a whole. It involves a thoughtful and conscientious approach to adopting digital solutions that address the specific needs and challenges of the agri-food sector, while minimising potential risks and negative consequences. Key aspects involve ethical use of data; equitable access to digital technologies and their benefits; prioritising digital solutions that contribute to sustainable agricultural practices, resource conservation, and environmental protection; co-creation and human-centred design; relying on research-based evidence to guide the adoption and scaling of digital innovations; interoperability and common standards fostering integration and data re-use; and responsible business models that prioritise social and environmental benefits alongside economic gains.

The Digital Innovation Initiative spearheaded by a team of 70 scientists in collaboration with local partners is committed to generating research-driven evidence that comprehends the mid and long-term implications of digital solutions. This implies researching on ethical considerations, biases, divides, accessibility, affordability, interoperability, and inclusivity of existing and future digital innovations in agri-food systems.

The session will showcase the progress of some of the case studies we have across the focus regions. These include a partnership with Farm Radio International, leveraging Artificial Intelligence to amplify extension services and empower 12 million sub-Saharan African farmers to voice their concerns. Scaling and adapting the digital diet quality monitoring developed in Rwanda for use in other regions. Additionally, an exploration into data wallets for small-holder farmers seeks to better understand the potential for data ownership as an asset in Mexico and India, while a digital twin approach in Southern Africa engages water resource management authorities to facilitate equitable resource allocation through efficient environmental flow management, water quality enhancement, and drought risk mitigation.

Keywords: Agri-food systems, data ownership, digital twins, equitable transformation, ethics, responsible digital innovation, sustainable agriculture

Contact Address: Jonathan Steinke, The Alliance of Bioversity International and CIAT, Digital Inclusion, Rome, Italy, e-mail: j.steinke@cgiar.org

ID 1005

CGIAR initiative on rethinking food markets: An overview and an example of preliminary results from Ethiopia

NICHOLAS MINOT

International Food Policy Research Institute (IFPRI), United States

Food markets in developing countries are under pressure to provide more nutritious foods at affordable prices while ensuring environmental sustainability and a fair return to farmers, particularly small-scale farmers. This presentation describes the CGIAR Initiative on Rethinking Food Markets. This Initiative is collaborative programme of applied research designed to identify interventions in food value chains that will reduce poverty, promote inclusion, and minimise environmental impact. Seven CG Centers are working on food value chains to test promising innovations and gather rigorous evidence of their impact on key outcome variables. The Initiative is divided into four work packages (WPs). WP1 focuses on testing interventions to improve value chains for export commodities, while WP2 carries out similar studies on food commodities marketed domestically. WP3 examines cross-commodity services such as finance and logistics. And WP4 is also building a knowledge platform to share resources, tools, and results related to the analysis of food markets. The case studies are located in Honduras, Guatemala, Nigeria, Uganda, Ethiopia, Uzbekistan, and Bangladesh. The presentation also provides preliminary results of one subcomponent of the Initiative that explores the impact of exchange rate controls in Ethiopia on farmers growing coffee, sesame, and other export crops. Exchange rate controls reduce the local-currency value of export revenue, acting as a tax on export commodities. This analysis shows the impact of this policy on farm income and, indirectly, on rural poverty. The results confirm that macroeconomic policies can have powerful effects on individual commodity sectors, potentially overwhelming programmes to strengthen value chains.

Keywords: And exchange rate, exports, finance, food, logistics, marketing, value chains

Contact Address: Nicholas Minot, International Food Policy Research Institute (IFPRI), Washington, United States, e-mail: N.MINOT@CGIAR.ORG

Research cooperation for sustainable development (BMBF/DLR session)

Oral Presentations

Research cooperation for sustainable development (BMBF/DLR session)

Kirsten Kienzler[1], Mikhail Rusakov[2]

[1]*DLR-Projektträger, Abteilungsleiterin Zusammenarbeit mit Staaten des Östlichen Europas (ohne EU), Südkaukasus, Zentralasien, Germany*
[2]*DLR-Projektträger, Wissenschaftsreferent, Germany*

The Federal Ministry of Education and Research (BMBF) promotes research cooperation between German research institutions and its partners around the world. One of the central objectives of such promotion is the development of contributions to solving societal and global challenges, resulting in a wide range of funded research projects. Among the priorities of research funding is the advancement of research on questions related to the UN-SDGs. In this context, the BMBF promotes the international research cooperation presented here from the thematic priorities of biodiversity research, environmental research, energy supply and research on the sustainable security of food resources. In the context of recent geopolitical developments (keyword "Zeitenwende"), cooperation with scientists from the South Caucasus and Central Asia has become even more important. In addition to this, these regions offer excellent research opportunities for developing regional solutions to global challenges, even in a global comparison. In the "Research Cooperation for Sustainable Development" session, four BMBF-funded research projects are presented, followed by a discussion between researchers on the opportunities and relevance of involving young scientists in state-of-the-art research specifically in the field of sustainability. In addition, current activities and research funding programs of the BMBF with a focus on the regions of non-EU Eastern Europe, South Caucasus and Central Asia are presented in the session.

With contributions and project examples by:

- Dr. Nils Hein, Leibniz-Institute for the Analyses of Biodiversity Change (ZFMK, LIB), Berlin: *Project CaBOL - Caucasus Barcode of Life - Assessing the Biodi-versity of the Caucasus*
- Dr. Karsten Rinke, Helmholtz-Centre for Environmental Research (UFZ), Magdeburg: *Project SEVAMOD2 - Establishing knowledge-based management for the largest lake in the Caucasus (Lake Sevan, Armenia)*
- Dr. Irina Hopp, Justus-Liebig-University Gießen: *Project TRANS-LIVESTOCK - Challenges and opportunities for value chains in trans-border livestock trade be-tween Tajikistan and Uzbekistan*
- Dr. Paul Bertheau, Reiner-Lemoine-Institute (RLI), Berlin: *Project Green-HyRECA – Production potential of green hydrogen in Central Asia*

Contact Address: Mikhail Rusakov, DLR-Projektträger, Wissenschaftsreferent, Bonn, Germany, e-mail: mikhail.rusakov@dlr.de

ID 1007

Payments for ecosystem services: Win-Win solutions? (BMZ/GIZ session)

Payments for ecosystem services: win-win solutions? (BMZ/GIZ session)

Claudia Ringler

Session chair, International Food Policy Research Institute (IFPRI), United States

Five out of six farms in the world are operated by smallholder farmers who produce around a third of the world's food. These farms provide a wide range of additional ecosystem services, such as carbon storage, pollination as well as cultural and supporting services. However, smallholder farm families face continued and often growing challenges to eke out a living from their farms and tend to be the poorest and most food-insecure populations in low-and middle-income countries. There is evidence that payments for ecosystem services can diversify smallholder earnings and incentivize more sustainable farming and land management practices. While a number of such smallholder focused schemes have been implemented around the world, they have, by and large, not gained sufficient traction to make a difference for farm incomes or environmental outcomes.

This second seminar of the CGIAR Policy Seminar Series on Strengthening Food Systems Resilience (https://www.ifpri.org/spotlight/cgiar-seminar-series-food-systems-resilience) examines past and ongoing ecosystem service payment schemes targeted at smallholders, evaluates their effectiveness and impacts and explores how such schemes could be taken forward if they are to become a key building block in building greater resilience into food systems. Speakers include:

- Johan Swinnen, IFPRI Director General, Managing Director of CGIAR Systems Transformation Science Group
- Felicitas Röhrig, Senior Policy Officer, Division of Agriculture and Rural Development
- Marcela Quintero, Associate Director General, Research Strategy and Innovation for the Alliance of Bioversity and CIAT; Senior Director Food Systems Transformation Science Group
- Claudia Ringler, IFPRI, Director of Natural Resources and Resilience

Contact Address: Claudia Ringler, International Food Policy Research Institute (IFPRI), 1201 Eye Street NW, 20005 Washington, United States, e-mail: c.ringler@cgiar.org

Leveraging human rights-based action towards equitable food systems: A panel discussion (BMEL/BLE session)

Oral Presentations

Leveraging human rights-based action towards equitable food systems

Maja Clausen[1], Dr. Lisa Jäckering[2]

[1]*Federal Ministry of Food and Agriculture (BMEL), Division 123, Research and Innovation, Coordination of Research Area, Germany*

[2]*Federal Ministry of Food and Agriculture (BMEL), Division 624, International Projects, Twinning, Germany*

The German Federal Ministry of Food and Agriculture (BMEL) is committed to promote the transformation towards resilient and rights-based food systems globally.

Strengthening the realisation of the right to adequate food, BMEL established several funding instruments of global reach, such as the "Research Cooperation for Global Food Security and Nutrition". Through this instrument, practice oriented trans- and interdisciplinary research projects contribute to improving global food security and nutrition, with a particular focus on small-scale farmers in the target regions Sub-Sahara Africa, South and Southeast Asia. The projects co-create needs-oriented knowledge and strengthen local capacities while also elaborating inputs for policy makers and promoting the interaction between relevant actor groups. The Federal Office for Agriculture and Food (BLE) acts as project executing agency.

In addition, the human right to adequate food guides the engagement of BMEL in the Bilateral Cooperation Programme and the Bilateral Trust Fund at the FAO.

In the BMEL-Session, the funding instruments that support a rights-based transformation of food systems will be presented and experiences shared by an expert panel. Thus, revealing recommendations to drive systemic change.

1. Dr. Georges Djohy, University of Parakou, Benin, project 'Enhancing women's agency in navigating changing food environments to improve child nutrition in African drylands (NaviNut)'.
2. Sarah Luisa Brand, Food and Agriculture Organisation of the United Nations (FAO).
3. Dang To Kien, Social Policy Ecology Research Institute (SPERI), Vietnam, project 'Nutrition Intervention Forecasting and Monitoring (NIFAM)'.
4. Dr. Andreas Gramzow, GFA Consulting Group GmbH.

Contact Address: Sunilda Terre Fornies, Federal Office for Agriculture and Food (BLE), Div. 334 – Climate, Global Food Security, International Cooperation, Deichmanns Aue 29, 53179 Bonn, Germany, e-mail: Sunilda.Terre-Fornies@ble.de

Seeds of change

Strategies for enhancing productivity and resilience of pearl millet in stress environments of Rajasthan, India

Oм Parkash Yadav

ICAR-Central Arid Zone Research Institute (CAZRI), India

Pearl millet is valued for its nutrient-rich grain for human consumption and its green fodder and dry stover for livestock and forms the basis of livelihood and nutritional security in arid and semi-arid regions of South Asia and sub-Sahara Africa (SSA). Its cultivation is largely concentrated in India, Niger, Sudan, Nigeria, Mali, Burkina Faso and Chad and is challenged by abiotic and biotic stresses. The purpose of this article is to consider the impact of research strategies in pearl millet improvement targeting stress-prone Rajasthan state of India and then to assess relevance of these strategies for western and central Africa where pearl millet is cultivated in similar agro-climatic conditions. Strategies to enhance the productivity in stress environments have centreed on development of new cultivars (largely hybrids with niches areas for open-pollinated varieties) with higher production potential and built-in resistance to diseases. Strategic use of genetic resources from India and SSA remain the key points in breeding of diverse hybrids and open-pollinated cultivars. A large number of cultivars have been developed and deployed in Rajasthan during last four decades leading to productivity increase from 254 kg ha^{-1} in 1980 to 892 kg ha^{-1} in 2019. Adoption of improved cultivars in highly risk-prone arid regions of India highlights their significant role in raising crop productivity even in marginal areas. These results have great significance to justify similar investment is research and development efforts and policy intervention in pearl millet for SSA.

Given pearl millet becoming more vulnerable to ever changing climatic conditions, enhancing its resilience to drought remains the key issue. Understanding pearl millet response to drought and dissection of drought tolerance physiology and phenology has helped in identifying target traits for manipulation in breeding for drought tolerance. The role of adapted germplasm has been emphasised. Hybridisation of adapted landraces with selected elite genetic material has been found effective to amalgamate stress adaptation and high productivity. Recent advancements in high-throughput phenotyping and genotyping platforms have made it more realistic to apply markers-assisted selection in breeding programmes targeting drought tolerance.

Keywords: Adaptation, breeding, cultivars, drought, pearl millet

Learning processes to foster 'localised' innovation in food and farming systems

Brigitte Kaufmann[1], Anja Christinck †[2], Margareta Lelea[1], Christian Hülsebusch[1]

[1]*German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*
[2]*formerly: German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*

Food and agriculture systems are human activity systems that are created, maintained and continuously changed, adapted and developed by "real" actors through their activities. Research that engages these actors in collaborative learning processes can pave the way for effective "localisation" of innovations.

The term "local" is used here to emphasise the contextuality of innovations, i.e. their validity within a particular local configuration that is influenced by environmental, economic and social conditions, by management strategies and techniques, by organisational forms, normative ideas and other factors. Exploring the contextual factors that need to be considered when trying to make innovation 'work' in a particular situation requires a variety of approaches, knowledge and skills.

In our work with the late Dr Anja Christinck, we conceptualised and used collaborative learning to systematically 'localise' or 'contextualise' innovations so that they become meaningful and relevant to real world actors in their respective local contexts. In this paper, we show that different types of innovations need to be contextualised to different degrees, depending on whether a first, second or third learning loop is required to integrate an innovation into an activity system.

Effective contextualisation of innovation processes must start with the identification of all relevant actors in a human activity system and their clearly defined active participation in the collaborative research process. The knowledge of the different actors is integrated, i.e. explicit knowledge is shared and an attempt is made to make explicit tacit knowledge that is normally embedded in activities and processes. Co-creation of knowledge can be achieved by experimenting with new technological options, processes or organisational structures in the local context so that new knowledge is put into practice. Conceptualising this process helps to advance the scientific understanding of innovation processes in food and farming systems.

Keywords: Collaborative learning, contextualisation, innovation, low external input systems

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Contact Address: Brigitte Kaufmann, German Institute for Tropical and Subtropical Agriculture (DITSL), Steinstrasse 19, 37213 Witzenhausen, Germany, e-mail: b.kaufmann@ditsl.org

Seeds in organic farming in Indonesia: Falling through the sieves of regulation and practice

Martina Padmanabhan

Passau University, Chair of Critical Development Studies, Germany

Organic agriculture relies on agrobiodiversity to unfold the potential of site-specific farming practices. Seeds are a central aspect of these social-ecological artefacts as the outcome of hundreds of years of intimate interaction between people and plants. The regulatory framework officially governing the emerging organic sector poses challenges to the procurement, exchange and handling of seeds in Indonesia. Based on extended interviews with breeders, farmers, activists and entrepreneurs in organic farming between 2017 and 2019, I reveal the contradictory seed management at the level of governance, and politics as well as innovative practices for transformation. As Laksmana (2023) shows, there is insufficient clarity in organic farming regulations on what constitutes organic seeds (BSN 2016). The Law No. 12/1992 on the Plant Cultivation System in Indonesia makes it illegal for farmers to use non-state-registered seeds. Organic farmers run in danger to be prosecuted for attempting to become more independent by storing and using their own seeds, while the state simultaneously encourages the use of local resources in organic agriculture. On the other hand, Laksmana and Padmanabhan (2021, 87–88) demonstrate how seed sovereignty, defined as farmers' rights to access, reproduce, and save seeds (Kloppenburg 2010) becomes central to farmers identifying and engaging with the concept of food sovereignty. Thinking through different concepts of seed governance aligned to private property, stewardship and commons, I juxtapose the regulatory ideas with the practices and imaginaries of practicing farmers, activists and breeders to throw light on the contradictory and potentially harmful environment disincentivizing agrobiodiversity maintenance and use.

Keywords: Agrobiodiversity, breeding, Indonesia

Contact Address: Martina Padmanabhan, Passau University, Chair of Critical Development Studies, Dr.-Hans-Kapfinger-Straße 14b, 94032 Passau, Germany, e-mail: martina.padmanabhan@uni-passau.de

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Pearl millet breeding for agroecology: Biodiversity considerations in West Africa

Eva Weltzien[1], Kassari Ango[2], Inoussa Drabo[3], Ghislain Kanfany[4], Moussa Daouda Sanogo[5], Ahmad Issaka[6], H. Frederick W. Rattunde[7]

[1]*University of Wisconsin-Madison, Agronomy, United States of America*
[2]*INRAN, Centre Maradi, Niger*
[3]*INERA, Pearl Millet Program, Burkina Faso*
[4]*ISRA, Pearl Millet Program, Senegal*
[5]*IER, Pearl Millet Program, Mali*
[6]*INRAN, Pearl Millet Program, Niger*
[7]*University of Wisconsin-Madison, Agronomy, Germany*

Agroecology as a movement and a science uses environmental and social principles for guiding food system transformation. The biodiversity principle addresses the maintenance and enhancement of genetic resources for functional diversity in agroecosystems over time and space. The agroecological movement, while focusing on strengthening farmers' seed management options, rarely uses support from scientific breeding. This study seeks to understand how national breeding programmes in West Africa address biodiversity issues relevant to agroecological transformation. Semi-structured interviews with pearl millet breeders, farmer-organisation and NGO representatives from Senegal, Mali, Burkina Faso and Niger provided the data for this study. All breeding programmes are collaborating with farmers to identify preferred traits and set priorities for variety development for specific agroecologies or uses. All of these programmes use local germplasm as the base for their breeding populations,and are thus contributing to conservation of these genepools. They also introduce new genetic diversity for new resistances to biotic and abiotic stresses. All breeding programmes evaluate their new selections in collaboration with farmer organisations, and thus support decentralised farmer decision making for seed production and dissemination. These findings show that breeding programmes and agroecology activists share many concerns. Thus, there is a solid basis for enhancing biodiversity through more direct collaboration between farmers, activists and pearl millet breeders in West Africa. These opportunities will be discussed.

Keywords: Plant breeding, *Pennisetum glaucum*, West Africa

Contact Address: Eva Weltzien, University of Wisconsin-Madison, Agronomy, Madison, United States of America, e-mail: eva.weltzien@gmail.com

DAAD Alumni seminar

Nature´s contributions to sustainable agriculture in tropical landscapes

José Andrés Rodriguez Zumbado

International Union for the Conservation of Nature, Science Team, Costa Rica

Land use and land cover change (LUCC) is a primary driver of biodiversity loss in tropical landscapes, with annual and perennial non-timber crop production accounting for a significant proportion of threats to endangered vertebrates worldwide. Species rich tropical forest provide often ignored valuable services to food production systems and although the links are not always evident, these services represent the basis for alternative ways of producing food. Agroecology, farming systems that apply ecological concepts and principles, contributes to climate change mitigation by reducing emissions, recycling resources and prioritising local supply chains, and provides a balance between productivity and biodiversity conservation. The International Union for Conservation of Nature (IUCN)´s Red List of Threatened Species (RL) is the world's largest and most comprehensive data source on the conservation status of species for global biodiversity. Derived knowledge tools from the RL, such as the Species Threat Abatement and Recovery metric (STAR), the Red List Index (RLI) and the Integrated Biodiversity Assessment Tool (IBAT), are all built from this knowledge to provide updated, scientifically robust and standardised information for conservation action and sustainable development decision making. Particularly useful is the freely accessible geospatial information from the RL that is available for every assessed species. A scenario development will be performed using information from IUCN RL to identify species grouped by functional guild (pollinators, seed dispersers, predators, etc) and modelled to obtain maps of ecosystems services provisioning to surrounding agricultural landscapes. The objective of this case study is to highlight the vital contributions that biodiversity in tropical landscapes provide to food production systems in a spatially explicit manner. Special attention will be given to Endangered species that are national endemics, to showcase the critical role they play in sustaining human societies and the need of adapting farming systems to not only reduce the impacts on biodiversity but to be nature positive, creating value for humans and for biodiversity.

Keywords: Ecosystem services, IUCN Red List, land use change, tropical endemism

Contact Address: José Andrés Rodriguez Zumbado, International Union for the Conservation of Nature, Science Team, 118st, 40703 Belén, Costa Rica, e-mail: andres.rod.zumb@gmail.com

Development of climate-smart dryland rice varieties with consumer-preferred qualities for Ghana

Felix Frimpong, Maxwell Darko Asante, Paul Kofi Ayirebi Dartey, Francis Amoako-Andoh, Kirpal Agyemang Ofosu, Benedicta Nsiah Frimpong, Charles Afriyie Debrah, Sylvia Kafui Artcher, Michael Akuamoah Boateng, Samuel Abebresse, Hillary Mireku Bortey, Priscilla Francisco Ribeiro, Aisha Karim, Phyllis Aculey, Daniel Gamenyah, Sober Ernest Boadu, William Lelabi Kota, Elizabeth Norkor Nartey, Huss Cole Yameen, Esther Nseasom

CSIR - Crops Research Institute of Ghana, Cereals, Ghana

Ghana is a net rice importer due to a demand-supply imbalance, with a per capita consumption of >60 kg annually. Consumers in Ghana prefer long-grain aromatic rice that cooks fluffy but remains soft upon cooking. High-yielding varieties without these grain qualities do not appeal to farmers. About 90 % of rice cultivation in Ghana is done in rainfed lowland and upland ecologies, which are prone to drought stress. We report the development and plasticity of three new upland rice varieties that grow well under upland and rainfed lowland conditions and have excellent consumer-preferred cooking qualities. These varieties have average 4 and 6 MT/ha yields under upland and rainfed lowland conditions, respectively. We found all three upland varieties tasted better and more aromatic as NERICA 1 check but more appealing than NERICA 1. Lower amylose content of 24 % or less was recorded for the three upland varieties compared to NERICA 1, which was 29 %. The three upland varieties had longer panicles similar to NERICA 1 but no anthocyanin colouration on the petiole base or seed, ranking them 1st in terms of appeal. All three upland varieties differ in panicle colouration at maturity, with AG 4–18 appearing dry brown, AG 2–1 and AG 4–13 as a pale yellow. AG 2–1 differ with lots of pubescence on panicles, paddy or the seed coat, whereas pubescence was absent for AG 4–18 and AG 4–13. The development of consumer-preferred rice varieties that do well under upland and lowland conditions would facilitate the adoption of these varieties and result in the expansion of rice cultivation under drought-prone environments in Ghana.

Keywords: Ghana, morpho-physiological traits, smart-farming, sustainable rice, upland rice, yield

Contact Address: Felix Frimpong, CSIR - Crops Research Institute of Ghana, Cereals, Fumesua CSIR, P. O. Box 3785, Kumasi, Ghana, e-mail: felix.frimpong@yahoo.com

Sustainable production of pistachios in dealing with climate change in central plateau of Iran

Narges Saffar

SIPCEM Alumni Network, Iran

The topic of sustainable production of pistachios in the face of climate change is relevant in the context of food and agroforestry systems because pistachios are an important horticultural and agricultural product in Iran, with a high export value. Climate change poses a threat to the production of pistachios in central Iran, which has a unique habitat and climate for cultivating pistachios. In Iran, 90 varieties of pistachios are cultivated in an area of 530000 hectares, of which about 100000 hectares are related to pistachio seedlings. Compared to its competitors (American pistachios), Iranian pistachio nuts have the highest amount of fat, about 56 %, which, in addition to its beautiful appearance and unique taste, has distinguished it from other pistachios in the world.

The increase in temperature, changes in rainfall volume, intensification of drought in desert and subtropical areas, and change in the level of surface and underground water sources have made it challenging to maintain the production volume and quality of pistachios. Sustainable production of pistachios in Iran requires identifying approaches and solutions to combat climate change including the use of low-chill cultivars, controlling pests caused by climatic stress, and selecting the correct location for establishing new gardens.

To achieve a in achieve a high-quality product and sustainable production, it is also important to consider growth factors and stress indicators, including cold demand, watering rate, soil salinity, etc. in all stages from pollination and flowering to crop growth.

By applying these measures, it is possible to achieve high-quality pistachios and sustainable production that can contribute to food security and support the agricultural systems in Iran.

Keywords: Climate change, dehydration, export value, Iran, low-chill cultivars, pistachio, *Pistacia vera*, sand and dust

Contact Address: Narges Saffar, SIPCEM Alumni Network, Fereshteh Azadi, 17677-18686 Tehran, Iran, e-mail: parsnarsis@gmail.com

Brazilian *cabruca*: Agroforestry as a pathway to biodiversity conservation and food security for small cocoa farmers

THIAGO SABATINELLI RODRIGUES

Casa Torta Pirangi Sustainable Cocoa, Brazil

In the State of Bahia, Brazil, a traditional cocoa agroforestry system known as "*cabruca*" has been contributing to the preservation of a significant part of the original coverage of the Atlantic Forest, one of the 25 world's biodiversity hotspots. Cabruca is a diverse, dynamic and perennial system, resilient to climate stressors when compared to conventional cocoa production and other farming systems. Cocoa is cultivated using principles of agroforestry and syntropic agriculture, under the canopy of the Atlantic Forest, home to native and endemic species. The conservation of the large trees and the use of ecological farming practices contribute to the protection of a biome which provides valuable ecosystem services, particularly climate stabilisation, carbon sequestration and water availability for agriculture. Several initiatives are being undertaken to explore the potential of the cabrucas for the production of premium, value-added products (organic cocoa nuts, chocolate, nibs, cocoa honey, vinegar, cocoa pulp etc.), with a commercial value greater than the obtained in the commodity market. Exploiting a yet untapped (and promising) market of sustainable cocoa products can not only increase the income of families, but also improve crop diversity, access and stability of food supply to small farmers. The preservation of cabrucas, however, depends on the revitalisation of old small cocoa production units, improving their processes and products with ongoing technical assistance, scientific research, technological development and marketing. Agroforestry systems with cocoa cultivation are also an opportunity for other developing countries in Latin America, Africa and Asia, which account for all the global cocoa production.

Keywords: Agroforestry, Atlantic forest, biodiversity, cabruca, cocoa, food security

Contact Address: Thiago Sabatinelli Rodrigues, Casa Torta Pirangi Sustainable Cocoa, Fazenda Pirangi, lote 2, 45980-000 Prado, Brazil, e-mail: sabatinelli@gmail.com

Online fair trade organic food market from organised civil society

Erika Lucia Arias Ramirez[1], Lucero Adriana Blanco Zambrano[2], Laura Cabezas[3]

[1]*NGO Agrosolidaria Colombia, Colombia*
[2]*Agrosolidaria Colombia, Director in Teusaquillo sectional, Colombia*
[3]*Universidad del Bosque, Health and Environmental Institute, Colombia*

The 2030 Agenda considers in its development objectives SDG 12 responsible consumption and production as a model to contain deforestation rates in the world's tropical forests, that is, if we achieve SDG 12 we will be able to face the recovery of ecosystems and contribute to addressing global challenges, as important as those related to those addressed in SD 13 climate action and SDG 2 zero hunger. For this, the models that are proposed from the social bases can guarantee their sustainability, in addition they improve the governance processes from the local level until reaching the regional models. In order to avoid intermediation in the food value chains, 250 families with agricultural units of less than 5 hectares located in 85 municipalities of 7 different departments in Colombia offer 150 nutritious food products, every week directly to the centre of greatest consumption in the country, Bogota, with a weekly periodicity achieved through civil organisation, the use of computer tools and a supportive transport network. The process that began in 2020 when the confinement due to COVID began in Colombia, is sustained to date, with nearly 200 urban families that supply themselves with their products based on the principles of agroecology, organic models, artisan value-added products or systems in transition to organic. This fair market model has contributed to the agri-food processes strengthening consumption decisions in the city, as well as allowing the recovery of soils and the conservation of the ecosystems present in each of the agricultural units. In October 2021, the Health and Environment research centre from El Bosque university signed an agreement with Agrosolidaria to monitor the success of Agrosolidaria processes, taking into account the positive impact that 950 Colombian peasant families have organised to protect nature and their livelihoods.

Keywords: Agroecology, civil society, fair markets, farm to fork, governance, organic food, sustainable agriculture

Contact Address: Erika Lucia Arias Ramirez, NGO Agrosolidaria Colombia, Calle 17 # 4 - 16, Monterrey, Colombia, e-mail: monterrey@agrosolidaria.org

Ethnobotanical study on the utilisation of wild edible indigenous fruits in Miombo woodland of Tabora region western Tanzania

Michael Elias Mgalula, Anasia Elingaya Saria

University of Dar es Salaam, Mkwawa University College of Education, Tanzania

The wild edible indigenous fruits species play a significant role in the daily life of rural people living in developing countries. They are anticipated to have potentially nutrients, vitamins, minerals and fiber. However, the dynamics in land use, climate change and alteration of rural ecosystems and landscapes values on conserving biodiversity, some indigenous fruits have disappeared and others may be at risk of extinction. The objectives of this project were to document the knowledge on the diversity of wild edible indigenous fruits, the extent of utilisation and degradation threats in Western Tanzania. This research was based on extensive field surveys, land use and cover mapping using geospatial techniques, edible fruits collection, minerals, vitamins and proximate analysis of five consumed species of edible fruits, and interviews with the local people. The present study documented 51 wild edible indigenous fruits species, the most abundant are *Vitex mombassae* 14.4 %, *Strychnos cocculoides* 14.1 %, *Vitex doniana* 12.2 %, *Phyllanthus engleri* 8.5 %, *Friesodielsia obovata* 8.6 %, *Tamarindus indica* 6.5 %, *Parinari curatellifolia* 5.3 %, *Grewia conocarpa* 4.6 % and the remaining species 0.2 % - 4.0 % are rare. Of the species identified, (34.5 %) are available after rainy season (April, May and June), (31.1 %) during dry season (July, August and September), (26.1 %) before rainy season (October, November) and only (8.3 %) are available year-round. The wild edible indigenous fruits have multiple uses as food (68.3 %), medicine (19.7 %), and (12.0 %) are preferred as vitamin supplement. The result showed mineral elements potassium, magnesium and calcium were present in substantial amounts in most fruits ranging from 487 to 1650.2 mg/100g. *Vitex doniana, Strychnos cocculoides*, and *Parinari curatellifolia* had the highest content of five mineral element (i.e. Fe, Ca, Na, Mg, K). The fruits *Phyllanthus engleri, Grewia conocarpa, Strychnos cocculoides, Vitex doniana*, and *Parinari curatellifolia* showed the presence of vitamin B9, A, and C. The diseases cured using indigenous fruits in the study areas are stomach problems, cough respiratory infection, reproductive problems, urinary infection and blood pressure. Besides that, the indigenous fruits on miombo forest of western Tanzania are threatened by increasing human activities 52.2 % and environmental and climate change 47.8 %. Overall, the study showed that

Contact Address: Michael Elias Mgalula, University of Dar es Salaam, Mkwawa University College of Education, P.O. Box 2513, MUCE, Iringa, Tanzania, e-mail: mgalulamike@yahoo.com

the fruits have substantial nutrients, minerals, essential vitamins and fiber required to maintain health of rural communities, therefore, these fruits require commercial markets in order to add value, and a holistic approach in the conservation of indigenous species with edible fruits in the forest and rangelands is needed. By doing that, the United Nations Sustainable Development Goals (12, 15) set by 2030 and 2063 African Development Agenda can be achieved.

Keywords: Nutritional benefits, use of edible fruits, value addition and conservation

Resource potential of bamboo, challenges and future directions towards sustainable management and utilisation in Ethiopia

Haweni Habtamu

Ethiopia Environmental Protection Authority, Environmental Pollution Status Monitoring and Control, Ethiopia

Bamboo is an important natural resource that has versatile socio-economic uses and ecological services. As the fastest-growing and a high-yielding perennial plant of the world with more than 1500 species and 1500 versatile socio-economic uses and ecological services. It has the potential to contribute to the bioeconomy as a source of high-value products and environmental benefits. In the context of sustainable production and consumption, bamboo has gained significant attention due to its potential to provide sustainable solutions for a range of industries, including food and agroforestry systems.

In Ethiopia, bamboo resources are particularly significant as they cover one million hectares with a wide distribution of two indigenous species, namely *Oxytenanthera abyssinica* and *Yushania alpina*. These species constitute 67 % of African bamboo and 7 % of the world's bamboo.

However, despite the socio-economic and environmental benefits of bamboo, it faces several challenges in Ethiopia. The current pressure on bamboo resources is due to land use changes, bamboo mass-flowering, poor processing with low-value addition, and damage by bio-deteriorating agents such as termites, beetles, and fungi.

This case study focuses on the potential of bamboo resources in Ethiopia, the challenges faced including biodeterioration damage, opportunities, and future research directions toward its sustainable management and rational consumption.

The case study emphasises the importance of integrated research and development interventions involving different propagation and management techniques, harvesting age and season, processing, value addition including proper seasoning and preservation technologies and marketing.

The relevance of this topic in the context of food systems and forest products is crucial. Bamboo-based products can provide sustainable alternatives to traditional products such as timber, which can lead to deforestation and the destruction of habitats for various species. Bamboo can provide sustainable solutions for a range of industries, including food systems and agroforestry systems.

Overall, the project contributes to the fulfilment of Six of the 17 Sustainable Development Goals (SDGs), such as poverty reduction; energy; housing and urban development; sustainable production and consumption; climate change and land degradation.

Keywords: Bamboo, *Oxytenanthera abyssinica*, sustainable management, *Yushania alpine*

Contact Address: Haweni Habtamu, Ethiopia Environmental Protection Authority, Environmental Pollution Status Monitoring and Control, Arat kilo, Addis ababa, Ethiopia, e-mail: haweni2h@gmail.com

Storage and distribution of soil organic carbon, total nitrogen and CO_2 emissions in semi-arid soils

Chukwuebuka Christopher Okolo[1], Girmay Gebresamuel[2], Amanuel Zenebe[2], Mitiku Haile[2], Jephter Ebuka Orji[3], Chinyere Blessing Okebalama[4], Chinedu Emmanuel Eze[5], Emmanuel Eze[6], Peter Ndubuisi Eze[7]

[1]*Jimma University, Natural Resources Management, Ethiopia*
[2]*Mekelle University, Dept. of Land Res. Manag. and Environ. Protection, Ethiopia*
[3]*Alex Ekwueme Federal University Ndufu-Alike, Dept. of Agriculture, Nigeria*
[4]*University of Nigeria, Dept. of Soil Science, Nigeria*
[5]*Michael Okpara University of Agriculture, Dept. of Agronomy, Nigeria*
[6]*University of Education Heidelberg, Dept. of Geography - Research Group for Earth Observation (rgeo), UNESCO Chair On World Heritage & Biosphere Reserve Observation and Education, Germany*
[7]*Botswana International University of Science & Technology, Dept. of Earth & Environmental Science, Botswana*

This study aims to investigate soil organic carbon (SOC) and total nitrogen (TN) contents and stocks, and CO_2 emissions in croplands, grazing lands, exclosures and forest lands of semi-arid Ethiopia. Sampling was done at 0–30, 30–60 and 60–90 cm soil depth and concentration and stocks of SOC, TN and selected soil properties were determined using routine laboratory procedures. There were variations in distribution of SOC and TN stock over 90 cm depth across land use types and locations, decreasing from topsoils to subsoil, with average values ranging from 48.68 Mg C ha^{-1} and 4.80 Mg N ha^{-1} in Hugumburda cropland to 303.53 Mg C ha^{-1} and 24.99 Mg N ha^{-1} in Desa'a forest respectively. Forest sequestered significant higher SOC and TN stock, decreasing with depth, compared with other land uses. In Desa'a and Hugumburda, the conversion of forest to cropland resulted in a total loss of SOC stock of 9.04 Mg C ha^{-1} and 2.05 Mg C ha^{-1}, respectively, and an increase in CO_2 emission of 33.16 Mg C ha^{-1} and 7.52 Mg C ha^{-1} yr^{-1}, respectively. The establishment of 10-year (Geregera) and 6-year (Haikihelet) exclosures on degraded grazing land increased SOC stock by 13 % and 37 % 1 respectively. Clay content and precipitation partly modulated SOC distribution, with high SOC content recorded in soils with high clay content and precipitation. Exclosure establishment on degraded ecosystem has shown to be a sustainable restoration pathway with significant improvement in soil properties and C sequestration. Loss of SOC stocks associated with land use conversion can be reversed in degraded croplands with the introduction of sustainable soil management practices (residue retention, integrated soil nutrient management, reduced tillage impact) in view of mitigating climate change impact.

Keywords: Cambisols, land use change, soil organic carbon sequestration, soil processes, vertisols

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Contact Address: Chukwuebuka Christopher Okolo, Jimma University, Natural Resources Management, Jimma, Ethiopia, e-mail: okolochukwuebuka@gmail.com

Competition on land between food crop and other land use in Indonesia

Nina Novira

Universitas Negeri Medan, Geography Education, Indonesia

Indonesia has since long aimed for self-sufficiency in several essential food commodity such as rice, sugar, and soy bean. In the course of its implementation, more focus has turned to rice than to other crop. However, after achieving self-sufficiency in 1984, the country has never been able to achieve it again. With increasing population, competition on land is tightening. In urban and urban fringe area, rice fields are converted into settlement or business complex, while in rural area, the farmers turned to other drop considered more profitable, such as oil palm. This study aims to discuss the competition on land faced by food crop in Indonesia. The case study is done in three urban fringe areas for the conversion of rice field to urban uses and in four rural areas for the conversion of rice field to cash crop. Results show that in the three urban fringe areas, the pressure of urban area has caused the conversion of rice field to settlement and other built-up area. In the four rural area, the perception of low profitability of rice and the perception of high profitability of oil palm has driven the conversion of rice fields into oil palm estate. There are many other things affected the conversion of rice field to other uses, such as the high workload of rice farming, inefficient subsidies, ineffective agricultural advisor system, and the position of rice farmers as merely rice growers in the rice production system and not rice businessmen. This will be further discussed in the presentation.

Keywords: Cash crop, competition on land, food crop, rice field, urban uses

Contact Address: Nina Novira, Universitas Negeri Medan, Geography Education, Jl. willem iskandar pasar V, 20221 Medan, Indonesia, e-mail: ninanovira@unimed.ac.id

Smallholders and ecological restoration: Understanding local perspectives and priorities in southeast Brazil

Mayra Flores Tavares[1], Patrícia Gallo[2], Mélanie Feurer[1]

[1]*University of Freiburg, Chair of Silviculture, Germany*

[2]*Technische Universität Dresden, Centre for International Postgraduate Studies of Environmental Management (CIPSEM), Germany*

Brazil's small rural producers (RPs) play a critical role in ensuring food security, biodiversity conservation, and natural resource protection. However, complying with the Native Vegetation Protection Law (NVPL), the primary legislation for ecological restoration (ER), remains a challenge for most landowners. This study aimed to better understand the motivations and barriers faced by rural producers when deciding to engage in restoration activities. We conducted semi-structured interviews with 68 landowners in the working area of a local restoration NGO in Brazil's Atlantic Forest, out of which 31 were rural producers, making them relevant for this study.

Most of the RPs in our sample were smallholders engaged in the conventional production of coffee and horticulture. About 90 % of respondents had restored at least a small area of native forest, primarily using natural regeneration as a restoration technique. Although agroforestry management is allowed in the restoration area, it was not mentioned by the participants. Protecting and increasing water availability was the main motivation for restoration, cited by 61 % of respondents. However, loss of productive land and income were the most frequently mentioned barriers to restoration due to their anticipated negative impact. Almost 70 % still need to restore their land to comply with the NVPL, with Payment for Ecosystem Services (PES) cited as the main incentive for restoration by RPs. The study results indicate that agricultural production is the primary focus of most RPs, and their decision-making is often based on this objective. Therefore, programmes that provide economic benefits, such as PES, could help incentivize restoration and compliance with environmental laws. Another incentive could be systems that generate alternative income from ER, including agroforestry. However, these techniques need to be promoted and analysed to assess their suitability and acceptance in the context. In conclusion, involving RPs in the design of ER projects is critical. This study has shown how understanding their characteristics and perspectives can lead to better strategies to support the engagement of landowners in the implementation of ER and, consequently, compliance with environmental laws.

Contact Address: Mayra Flores Tavares, University of Freiburg, Chair of Silviculture, Freiburg, Germany, e-mail: mayra.tavares@waldbau.uni-freiburg.de

Effectiveness of biopesticides for aphid pest management in wheat

Nimra Batool, Shafqat Saeed, Muhammad Nadir Naqqash

MNS-University of Agriculture Multan, Inst. of Plant Protection, Pakistan

Wheat is a potential crop that could meet the country's food requirements. Insect pests are a key source of yield losses in the wheat crop. Aphids are among the economic yield reducing major pests of wheat. Aphid management is an essential aspect of increasing wheat yields. The cherry oat aphid, Rhopalosiphum padi Linnaeus, green bug, Schizaphis graminum Rondani, and corn leaf aphid, Rhopalosiphum maidis Fitch (Hemiptera: Aphididae) are all recorded to damage the wheat crop. Insecticides are used exclusively to control pests. Additionally, increasing applications of synthetic insecticides have resulted in higher resistance and pest resurgence. Alternatively, the use of botanicals along with insecticides can affect the activity of the aphid. The current research has been planned keeping in view the importance of managing aphid pests. The study evaluated the effectiveness of botanicals i.e., Neem, *Azadirachta indica* A. Juss, Kortuma, *Citrullus colocynthis* Linnaeus, Tobacco, *Nicotiana tabacum* Linneaus, silver nanoparticle spray, S1 bacteria (S1B), Biopesticide (Bio-N), one insecticide Advantage, and Control on wheat aphid and their biological control i.e., ladybird beetle, Syrphid fly, and *Chrysoperla carnea* Stephens. Field experiments was done on wheat crops in the MNS-University of Agriculture, Multan experimental areas. Randomised complete block design under factorial was followed with three replications. Data was recorded before and after 24, 48, 72 and 168 hours. Research on the population dynamics of different species of aphids revealed significant differences in the treatments of kortuma, Ag nanoparticle, and Bio-N treatments. There was a significant population of ladybird beetle/plant found in the case of kortuma and sliver nanoparticle treatments during 2nd week of spray ($p < 0.05$). The data showed that the effect of biopesticide like Ag nanoparticle, Bio-N and kortuma was relatively better as compared to all other treatments because of less resistance. Aphid populations were higher in the control case and certain other biopesticide treatments like neem, tobacco and S1 bacteria after particular hours. The data obtained revealed that biopesticides had a considerably better effect than conventional treatments because of reduced resistance and the fact that it was produced under natural conditions.

Keywords: Aphid, biological control, biopesticides, botanicals, management, wheat

Contact Address: Nimra Batool, MNS-University of Agriculture Multan, Inst. of Plant Protection, Manzoorabad Block A, 66000 Multan, Pakistan, e-mail: nimrabatool1133@gmail.com

Quantifying contributions towards reducing species extinction risk through sustainable agriculture in tropical landscapes

José Andrés Rodriguez Zumbado

International Union for the Conservation of Nature, Science Team, Costa Rica

Land use and land cover change (LUCC) is a primary driver of biodiversity loss in tropical landscapes, with annual and perennial non-timber crop production accounting for a significant proportion of threats to endangered vertebrates worldwide. Species rich tropical forest provide often ignored valuable services to food production systems and although the links are not always evident, these services represent the basis for alternative ways of producing food. Agroecology, farming systems that apply ecological concepts and principles, contributes to climate change mitigation by reducing emissions, recycling resources, and prioritising local supply chains, and provides a balance between productivity and biodiversity conservation.

The IUCN´s Red List of Threatened Species (RL) is the world's largest and most comprehensive data source on the conservation status of species for global biodiversity. Derived knowledge tools from the RL, such as the Species Threat Abatement and Recovery metric (STAR), the Red List Index (RLI) and the Integrated Biodiversity Assessment Tool (IBAT), are all built from this knowledge to provide updated, scientifically robust and standardised information for conservation action and sustainable development decision making. Particularly useful is the freely accessible geospatial information from the RL that is available for every assessed species. A scenario development will be performed using the STAR metric to compare agricultural landscape and forest cover to measure the contribution to reducing species extinction risk of endangered species. The objective of the case study is to highlight the vital contributions that sustainable agricultural practices provide to biodiversity conservation in tropical landscapes in a spatially explicit manner. Special attention will be given to Endangered species that are national endemics, to showcase the critical role they play in sustaining human societies and the need of adapting farming systems to not only reduce the impacts on biodiversity but to be nature positive, creating value for humans and for biodiversity.

Contact Address: José Andrés Rodriguez Zumbado, International Union for the Conservation of Nature, Science Team, 118st, 40703 Belén, Costa Rica, e-mail: andres.rod.zumb@gmail.com

The role of false banana (*Ensete ventricosum*) for sustainable agriculture in Ethiopia

Melesse Zeleke Agegnehu

Debre Markos University, Dept. of Agricultural Economics, Ethiopia

Agriculture is the mainstay of the Ethiopian economy. According to the Ethiopian Development Report (2022), it accounts for 75 % of the workforce, 40 % of the country's GDP, and 80 % of foreign exchange. Smallholder farming which is mainly characterised by rain-fed, low-input, and low-output farming systems is the major producer of food in Ethiopia. Thus, food insecurity and poverty have largely resulted from inefficient smallholders' agricultural productivity due to the depletion of forests, depletion of soil quality, reduction of soil microorganisms, over-grazing, desertification (extensive drying of the land), etc. in the country. Therefore, agriculture has to be sustainable in the sense that food production should be environmentally friendly. Thus, promoting sustainable farming can mean equipping farmers with Good Agricultural Practices (GAPs), such as the adoption of Agroforestry systems, planting food forests, planting covered crops, reducing or eliminating tillage, applying integrated pest management, avoiding soil erosion, managing the whole systems and landscapes, etc. In this regard, agro-forestry practices by false banana trees (Ensete), as one of the staple perennial crops, contribute a lot to soil fertility and agricultural productivity, and nutrition which in turn improve the food security in the countryside. The False banana is a native plant that is mostly grown in the less arid highlands of the southwestern region of Ethiopia. Nowadays, there is also potential for expanding the consumption of the crop in the northwestern side of the country. Even more, the production and consumption of false bananas play a prominent role in improving life on land (biodiversity), tackling the effects of climate change on agricultural production, and achieving zero hunger in the Ethiopian context. Therefore, this paper discusses the contributions, opportunities, and challenges of false banana production for smallholders in performing sustainable farming. It aims to provide information on both the benefits of false bananas for livelihood improvement, and its current situations for further adoption & dissemination of seedlings and planting trees in the whole areas of the country.

Keywords: Agro-forestry systems, enset, sustainable farming, zero-hunger

Contact Address: Melesse Zeleke Agegnehu, Debre Markos University, Dept. of Agricultural Economics, Abma 147, 269 Debre Markos, Ethiopia, e-mail: melesezeleke9@gmail.com

Promoting food security through conservation agriculture: A case study of intensifying sustainable farming practices among smallholder farmers in Zimbabwe

Oliver Kuwa

Zibagwe Rural District Council, Zimbabwe

Agriculture is a significant contributor to Zimbabwe's gross national product (GNP), yet the country has been plagued by perennial droughts, soil degradation, and limited machinery, resulting in low food production. According to the Food and Agricultural Organisation (FAO), crop yields need to increase threefold to feed the growing world population. Conservation agriculture, which promotes natural ecological processes to increase agricultural yields and sustainability by minimising soil disturbance, has been promoted by both donors and the government resulting in the participation of more than 1.8 million farmers in Zimbabwe. The primary objective of this case study is to investigate the hypothesis that conservation agriculture results in higher crop yields compared to conventional farming practices. By shedding light on how smallholder farmers in Zimbabwe can increase maize crop yields to improve household food security and nutrition, this study seeks to encourage the adoption of conservation agriculture practices. This case study will involve extensive literature reviews, key informant interviews, and field visits to examine the factors that have contributed to the low adoption of conservation agriculture by African smallholder farmers, such as farmers' resistance to change, knowledge and capacity gaps, and the withdrawal of donor support. The study will also highlight the benefits of conservation agriculture in improving food sufficiency. Investing in conservation agriculture is a suitable approach to promoting food security in Zimbabwe. The study will contribute to the body of knowledge on sustainable food systems by demonstrating the potential for conservation agriculture to increase agricultural yields and sustainability while minimising soil disturbance.

Keywords: Conservation agriculture, smallholders, Zimbabwe

Contact Address: Oliver Kuwa, Zibagwe Rural District Council, Zibagwe, Zimbabwe, e-mail: kuwaoliver@gmail.com

Forest-based bioeconomy in Argentina: Identifying social actors and dominant, marginal and alternative discourses

Julian Daniel Mijailoff[1], Sarah Lilian Burns[2]

[1]*National Scientific and Technical Research Council (CONICET) / Ecological and Environmental Systems Research Laboratory (LISEA), FCAyF, La Plata National University, Argentina*

[2]*TU Dresden, Inst. of International Forestry and Forest Product, Germany*

The expected contribution of this study focuses on the ongoing forest-based bioeconomy policy process in Argentina and the different visions and social actors associated with it. The concept of bioeconomy continues to spread worldwide leading to a panoply of bioeconomy-based policies and strategies. Nonetheless, there is no consensus over its definition, but rather different visions and ideas on its meaning, relating the concept to what can be defined as a floating signifier. As a result, local and national bioeconomy policy agendas draws on discourses and perspectives shaped by the political struggle over its meaning. In Argentina, the dominant vision on forest-based bioeconomy relates to a bioresource-based pro-economic growth vision relying on industrial tree plantations and promoted by the private sector and its interest groups. However, this fixation of meaning has marginalised alternative bioeconomy visions and actors, inhibiting the prospect of a more inclusive bioeconomy project.

The study aims to identify the different forest-based bioeconomy-related stakeholders in Argentina, including those excluded in mainstream public policy debates. We apply social network analysis techniques and discourse analysis on the base of data gathered through documental analysis and semi-structured interviews. Preliminary results indicate dominant visions promoted mainly by interest groups and two main discursive excluded communities: an academic complex related to biotechnology-oriented visions and civil society actors, including indigenous communities and local NGOs, associated with alternative bioeconomy visions where forest provide holistic livelihood, including non-timber forest products.

The topic is relevant in the context of food and agroforestry systems aiming sustainable production and consumption. The identification and recognition of different forest-based bioeconomy-related stakeholders are essential for the development of an inclusive and comprehensive bioeconomy that considers alternative visions and actors, including indigenous communities and local NGOs. Such an approach can contribute to sustainable production and consumption of forest-based products and services while considering the social, economic, and environmental aspects of the forest-based bioeconomy.

Keywords: Agro-forestry, Argentinia, bioeconomy

Contact Address: Julian Daniel Mijailoff, National Scientific and Technical Research Council (CONICET) / Ecological and Environmental Systems Research Laboratory (LISEA), FCAyF, La Plata National University, Godoy Cruz 2290, Caba, Argentina, e-mail: julianmijailoff@gmail.com

Identifying powerful actors in community forestry for effective sustainable forest management: A case study in Son La province

Bach Ngo Duy

Vietnam National University of Forestry, Ministry of Agriculture and Rural Development, Vietnam

Forest management is an essential aspect of sustainable forest use and conservation, ensuring that forests continue to provide essential ecosystem services and products that meet human needs while also maintaining ecological integrity. Community forestry, as a form of sustainable forest management, has been increasingly adopted in various countries, including Vietnam. However, the success of community forestry depends on the dynamics of social interactions among relevant actors and the context of political processes. Communities are vulnerable to the influence of powerful relevant actors. This study identifies 13 relevant actors involved in community forestry activities in the research site and applies the Äctor-Centered Powertheory to calculate the power elements of these actors, including Coercion, Incentive/disincentive, and Dominant information. Identification of the stakeholders involving in community forestry is based on the complete survey by doing interviews with selected user groups. The power elements are also examined through quantitative meausrements. The calculation of the power elements is relied on the four-point ordinal scale, each stakeholder is asked and labeled respective values based on the received information. The calculation results are cross-checked to ensure the credibility and validity of the results. The results indicate that political actors, particularly state agencies, are the most powerful actors steering community forestry process in all cases. This suggests that there is a need to improve the effect of community forestry activities by recognising the reality of communities managing their forests, strengthening stakeholder cooperation, and building beneficial mechanisms for communities participating in forest management. These solutions are important not only for sustainable forest management but also for promoting sustainable production and consumption into a circular economy approach, as forests play a crucial role in providing ecosystem services and resources for local communities and contributing to the global efforts in addressing climate change and biodiversity loss, supporting support the well-being of both people and the planet.

Keywords: Community forestry, Vietnam

Contact Address: Bach Ngo Duy, Vietnam National University of Forestry, Ministry of Agriculture and Rural Development, Hanoi, Vietnam, e-mail: bachvfu@gmail.com

Factors affecting availing of veterinary services in India: A regional perspective

Sumit Mahajan[1], Janailin Suchiang Papang[2], I. Panchal[1], B. Sharanagouda[1]

[1]Lala Lajpat Rai University of Veterinary and Animal Science, India

[2]Chaudhary Charan Singh Haryana Agricultural University, Dept. of Agricultural Economics, India

Increases in the population of crossbred cattle, whose higher productivity is accompanied by higher susceptibility to infectious and metabolic diseases, have been largely credited for the recent surge in growth rate of milk production in India. This has led to a greater need for high-quality, timely, and affordable veterinary services. Veterinarian services are primarily provided by the government in India. Given this context, the current study's goal was to identify the variables influencing the use of veterinary services from various sources. The study is based on the secondary data available from NSSO conducted in the year 2013. Decision to use veterinary services and its choice was hypothesised to be affected by access to veterinary services, milk production, operational land holding, principal income source, milk price, training, extension along with demographic factors. Considering the diversity of India, the data were divided into six regions and data were analysed for each of six regions and at all-India level using multinomial logit method. Exposure to extension agencies encouraged dairy producers in India to use institutional services. The marginal sections of the society were likely to not avail veterinary services, thereby affecting the productivity of the animals. Households who produced more milk were more likely to avail veterinarian services. The presence of veterinary hospitals/dispensaries in villages of Hills, East, and NE regions increased the probability of avaling their services by 9 %, 6 %, and 21 %, respectively. In the North and West regions, households with higher milk output were more likely to use veterinarian services from both institutional and non-institutional sources. In the Hills and West areas, receiving agricultural training increased the likelihood of using institutional veterinary services by 16 % and 7 %, respectively.

Keywords: Factors, NSSO, regions, veterinary services

Contact Address: Sumit Mahajan, Lala Lajpat Rai University of Veterinary and Animal Science, Haryana, India, e-mail: Sumitzone2009@gmail.com

Food security and sustainability through geographical indications (GIs) protection system for honeybee's producers communities within forest peripher

Sri Oktavia

Universitas Andalas, Indonesia

Connecting local farmers with their communities and their food products through Geographical Indications (GIs) is seen as a way to create a healthy food system and promote the growth of rural communities around the globe. The way food is made and where it come from, how different it is and whether people nearby can get it are important things that make a difference to sustainable food system. People in many places around the world have developed their own unique culture by making special food and living in a landscape that show how they use the land to make what they need. GI grants its holder a certification mark indicating that the specified product has the same qualities and is well-known due to its origin in the specified geographical location. Because GIs products tend to generate a premium brand price, they contribute to local employment creation, which ultimately may help to prevent rural exodus. Further, GIs may bring value to a region not only in terms of jobs and higher income, but also by promoting the region as a whole. In this regard, GIs may contribute to the creation of a "regional brand." This research aims at identify, inventory and map potential GIs honeybee products in Ujung Kulon National Park, Indonesia. GIs are more than just a name or a symbol. They reflect a reputation strongly linked to geographical areas of varying sizes, thus giving them an emotional component. A geographical indication's reputation is a collective, intangible asset. In recent years, the rate of GIs in Indonesia has increased notably, marked by annual increase in registration at the Directorate General of Intellectual Property Rights, Ministry of Law and Human Rights of the Republic of Indonesia. In contrast, if we look from the perspective of potential wealth of GIs products found in Indonesia, only a few are legally registered. As of March 2023, there have been 123 products, including 112 domestic products and 11 foreign products registered with GIs in Indonesia. To achieve the research objectives, two research questions have been addressed: (a) how the GIs can be protected trough legal framework both in international arena as well as in the Indonesian context?, (b) how to identify, inventory and map the potential GIs honeybee product in Ujung Kulon National Park?. This research is empirical legal research and employs socio-legal approach.

Keywords: Forests, honeybee, Indonesia

Contact Address: Sri Oktavia, Universitas Andalas, Padang City, Indonesia, e-mail: srioktavia@law.unand.ac.id

Socio-economic and ecologic factors for mobility of herder households in Mongolian steppe

Ganzorig Gonchigsumlaa[1], Sugar Damdindorj[1], Bumanjargal Gombodorj[1], Irene Ring[2], Ulan Kasymov[2], Marion Mehring[3], Nandintsetseg Dejid[4], Tserendavaa Tseren[1], Lukas Drees[3], Denise Margaret Matias[5], Thomas Mueller[4], Yun Jäschke[6]

[1]*Mongolian University of Life Sciences (MUL), Dept. of Statistics and Econometrics, School of Economics and Business (SEB), Mongolia*

[2]*TU Dresden, International Institute Zittau, Germany*

[3]*ISOE – Institute for Social-Ecological Research, Senckenberg, Biodiversity and Climate Research Centre SBiK-F, Germany*

[4]*Senckenberg Biodiversity and Climate Research Centre, SBiK-F, Germany*

[5]*Eberswalde University for Sustainable Development, Fac. of Forest and Environment, Germany*

[6]*Senckenberg Museum of Natural History Görlitz, Germany*

Mobile grazing has been identified as a superior environmental practice compared to sedentary grazing. This study examines the factors influencing herder mobility in Mongolia, considering the impact on rangeland degradation and environmental health.

In Mongolia, the number of livestock has increased significantly over the years, leading to overgrazing and environmental degradation. Studies have shown that approximately 70 percent of the grasslands in Mongolia have been degraded. The reduction in herder mobility since the 1990s, when Mongolia transitioned to a market economy and privatized livestock, has been influenced by social, economic and ecological factors such as increasing poverty, the increasing livestock density, declining terms of trade, lack of social services, and the loss of formal regulatory institutions. The research aims to address the the factors that affect to the herder household mobility in nomadic and pastoral livestock husbandry in Mongolia.

The semi-structured survey questionnaire was conducted at 11 coresites in four provinces of Mongolia between 2019–2022, excluding 2021, three years panel data of 253 herder households, that are selected stratified random selection method. We employed robust fixed effect econometric model for analysing the factors, and to validate the results we also tested ecometric models such as Pooled OLS, Pooled OLS robust, and RE robust models.

The findings reveal that certain social factors, such as the number of households grazing in the same area and drought, negatively affect herder mobility,

Contact Address: Ganzorig Gonchigsumlaa, Mongolian University of Life Sciences (MULS), Dept. of Agricultural and Applied Economics, School of Economics and Business (SEB), BLD of SEB, MULS, Zaisan, Khoroo 22, Khan-Uul District, 17024 Ulaanbaatar, Mongolia, e-mail: ganzorig.g@muls.edu.mn

while perceived vegetation cover after using seasonal pastureland positively influences mobility distance. Economic factors, including distance from the soum centre, moving in accordance with local government plans, availability of manpower, and the cost of mobility were also found to impact mobility decisions. Ecological factors include vegetation condition and water availability, grassland availability within administrative units, response to natural hazards such as drought and Dzud, household wealth.

By understanding the complex interplay of social, economic, and ecological factors, strategies can be developed to encourage herders to move farther and more frequently with their livestock, thereby mitigating the adverse effects of overgrazing and promoting environmental conservation.

Keywords: Environmental degradation, factors for herder mobility, herder mobility, livestock grazing

Promoting sustainable land use practices among the forest-dependent communities: Case studies of Vietnam

Thi Thuy Hong Do

Ministry of Natural Resources and Environment (MONRE), Vietnam

Vietnam has been recognised as one of the most biologically diverse countries in the world. It is reported with more than 13,200 floral species and about 10,000 faunal species identified in the terrestrial ecosystems of the country. It provides stability and resilience to the economy, especially agriculture, forestry and fisheries sectors, at the same time ensures food security for the people of the country. In addition, biodiversity is also an essential foundation for the livelihoods of many vulnerable communities in Vietnam. In fact, most of the people that live in the mountainous areas are ethnic minorities whose livelihoods are dependent in many ways on the forests. Yet, over recent decades, the natural resources systems in Vietnam have been deteriorating gradually due to the rapid and unsustainable development. In many mountainous areas in the country, shifting cultivation practices have led to deforestation and forest degradation in the watersheds of the mountainous area. This can result in flooding in the plains, and lead to climate change impact as consequences. Accordingly, these poor communities are especially more and more vulnerable due to increasing threats caused by climate change on their lives, their livelihoods and their food security.

Among efforts and interventions on the pathway to increasing forest protection and biodiversity conservation and at the same time increasing resilience for communities living in surrounding areas. This paper seeks to explore the possibility of applying low emissions land use practices toward livelihood sustainability for the poor communities that are forest-dependent as one of the solutions to address the mentioned issues.

Keywords: Biodiversity, forest protection, livelihoods, Vietnam

Contact Address: Thi Thuy Hong Do, Ministry of Natural Resources and Environment (MONRE), Hanoi, Vietnam, e-mail: Thuyhong.src@gmail.com

Body composition changes of male mice C57BL/6 fed high-fat diets supplemented with bovine milk coming from three feeding systems in subhumid tropics

Mario Cuchillo Hilario[1,4], Diego L. Ramírez-Ramírez[2], Lilia G. Noriega[1], Mariana López-Blanco [2], Mareli I. Fournier-Ramírez[3], Margarita Díaz-Martínez[1], Claudia Delgadillo-Puga[1]

[1]*Instituto Nacional de Ciencias Médicas y Nutrícíon 'Salvador Zubirán', Mexico*

[2]*Universidad Nacional Autónoma de México (UNAM), Fac. de Medicina Veterinaria y Zootecnia, Mexico*

[3]*Universidad Nacional Autónoma de México (UNAM), Dept. de Ciencias Pecuarias, Mexico*

The objective of this study was to compare the body weight, fat mass and lean mass in a mouse model fed with a high-fat diet (HFD) supplemented with lyophilized bovine milk coming from three feeding systems from sub-humid tropical of Yucatán, Mexico. The murine model consisted in 30 male C57BL/6 mice of 21 days of age and body weight of 24g. Mice were allocated into 5 groups (n=6). The experimental groups were: 1) CD= control diet (7 % fat); 2) HFD= high fat diet (21 % fat); 3) ISS= HFD plus 40 % lyophilized bovine milk from intensive silvopastoral system; 4) MS= HFD plus 40 % lyophilized bovine milk from monoculture system, and 5) NVS= HFD plus 40 % lyophilized bovine milk from native vegetation system. The rodents were fed ad libitum during 98 days; body weight and food intake were recorded once a week. Body composition (lean and fat mass) was evaluated in the day 77 by quantitative magnetic resonance (EchoMRI-700 TM; Echo Medical Systems, LLC. Houston, TX, USA). Data were analysed by one-way ANOVA and Tukey (α=0.05). HFD (36.8$\pm$3.5g) increased body weight ($p = 0.0248$) compared to CD (29.4$\pm$2.9g) and ISS (30.5$\pm$1.9g). However, all groups supplemented with cow's milk showed a tendency to lower body weight at greater extent than HFD. For lean or muscle mass, HFD obtained the lowest percentage (68.2$\pm$2.4g), being statistically different ($p = 0.0206$) to CD which showed the largest value (77.9$\pm$6.4g). No further differences were observed in the rest of groups. Even though, a rising trend was depicted from NVS (70.1 %) followed by ISS (75.2 %) and MS (76.4 %). In contrast to lean mass, fat mass percentage was maximum in HFD (29.5 %) being different ($p = 0.0206$) from CD (18.8 %) and ISS (19.2 %). The SM (20.0 %) and NVS groups (26.4 %) were not distinct from CD in this respect ($p = 0.9960$ and $p = 0.1902$, respectively). Cow's milk, could a non-pharmacologic approach to modulate metabolic alterations encouraged by a high fat diet. Supplementation cow's milk deflect excessive body weight gain while depleting body fat mass deposition.

Contact Address: Mario Cuchillo Hilario, Instituto Nacional de Ciencias Médicas y Nutrícíon 'Salvador Zubirán', Mexico City, Mexico, e-mail: mario.cuchilloh@incmnsz.mx

Improving household food security; the role of neglected and underutilised (NUS) species: Case study in Nkawie forest district

Mary Adu-Sarpong[1], Emmanuel Adu-Sarpong[2]

[1]*Timber Industry Development Division (TIDD) of Forestry Commission (FC), Ghana*
[2]*Forestry Commission, Ghana, Forest Business Planning, Ghana*

Sustaining food sources in Ghana is critical as the country imports basic foods costing an average of USD 2.4 billion yearly. Promoting diverse food sources from neglected and underutilised species (NUS) such as Grains of Paradise (GoP), Black Pepper (BP), Thaumatin, etc. is crucial. The study aimed at identifying specific NUS available in the study area, assessing Agroforestry practices used in the integration of NUS in the local landscape; and ascertaining contributions of NUS to household income. Participatory Rural Appraisal (PRA) tool together with a semi-structured questionnaire were used to elicit information. Both quantitative and qualitative data sources were employed and information obtained was triangulated using Focus Group Discussion. 147 farmers who have previously been introduced to the cultivation of NUS-based Non-Timber Forest Products (NTFPs) were used. Data were analysed using Statistical Package for Social Science (SPSS) and Excel sheets.

The result indicates that 30 % of NTPF-based NUS comprising Wild yams, GoP, BP, Thaumatin, tiger nuts, and agushie were available throughout the seasons. 87 % of farmers earning less than GHC 100.0 (USD 26) per week during the lean season whiles 88 % of farmers earn GHC 100.0 to 150.00 (USD 26–39) per week in harvesting/peak season.

Agroforestry models such as Trees-on-farm (83 %), crop-over-trees systems (20 %), intercropping and alley cropping (60 %), modified Taungya (90 %), cocoa smart agriculture (100 %) and other (20 %) were been practised by the smallholder farmers.

The study revealed that the availability of NUS supports household income. The explicit contributions to the smallholder farmer indicate that proper NUS attention and management could supplement the food system. The study is recommending that FC should consider setting up Business models to look into out-grower schemes to explore the business potential of the BP, GoP, and Thaumatin businesses to improve farmers' medium-term incomes to support MTS tree farms management.

Keywords: Food system, neglected and underutilised species, non-timber forest products

Contact Address: Mary Adu-Sarpong, Timber Industry Development Division (TIDD) of Forestry Commission (FC), Accra, Ghana, e-mail: adusarpongmary@gmail.com

Empowering jua-kali to combat mycotoxins in Kenya's maize supplies: A participatory design approach with transdisciplinary knowledge integration

Isaiah Etemo Muchilwa[1,2], Oliver Hensel[2], Franz Roman[2], Margareta Lelea[3]

[1]*Moi University, Kenya*
[2]*University of Kassel, Agricultural and Biosystems Engineering, Germany*
[3]*German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*

Kenya is overburdened by the high prevalence of mycotoxins that contaminate maize supplies. With a tropical climate favorable for fungal growth, these toxins compound health problems and erode progress to eradicate poverty and hunger. Technological deficiencies and the mishandling of harvests under wet weather conditions account together for losses of up to 30 % in annual crop yields, threatening the livelihoods of already impoverished communities. Despite advances in mechanized drying globally, these technologies are unavailable locally and hence are mostly imported to the detriment of local microenterprise, specifically to those involved in manufacturing – such as the Jua Kali in Kenya. This project sought therefore to co-create a homegrown mechanized drying solution, tapping into the creativity of local artisans, but with collaborative learning through knowledge infusion from farmers, engineers, scientists, and other societal stakeholders. Design of a novel encased-air cobbed maize dryer was premised on the findings of a successfully concluded DAAD sponsored PhD thesis at the University of Kassel, Section of Agriculture and Biosystems Engineering, with Jua Kali artisans involved in prototyping as part of the collaborative learning process. An iterative / continuous engagement was established between the researchers on the team and the artisans, generating ideas and testing to settle on a working prototype. A novel one hundred cob-bag (approx. 10 ton capacity) encased-air dryer was developed and tested successfully. The new system integrates solar heating and a Top-Lit Upward Draft (TLUD) biomass stove for continuous day/night operation using readily available crop residues (like maize cobs /stover) to dry the grain, ensuring low operating costs. Thermo-hygrometric sensors were integrated to facilitate remote monitoring of drying from mobile phones, to ensure sufficient dehydration. A growth in the confidence of the artisans engaging in problem solving was observed as a consequence of the collaborative learning engagements. The project was sponsored by the Volkswagen Foundation under the "Knowledge for Tomorrow – Cooperative Research Projects in sub-Saharan Africa" and the German Federal Ministry for Education & Research under the first German African Innovation Incentive Award (GAIIA).

Keywords: Aflatoxins, co-design, cob drying, maize

Contact Address: Isaiah Etemo Muchilwa, Moi University, Eldoret, Kenya, e-mail: imuchilwa@yahoo.co.uk

International partner projects - University of Applied Sciences Weihenstephan Triesdorf

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Posters

Nutritional, microbial and sensory of complementary food from kocho, orange-fleshed sweet potato and haricot bean

GEZAHEGN NIGUSSE KELIKAY, TADEWOS HADERO MEDALICHO, łinebreakTAREKEGN YOSEPH SAMAGO

Hawassa University, School of Nutrition, Food Science and Technology, Ethiopia

Protein energy malnutrition and vitamin A deficiency in children associated with poor nutritional knowledge resulting in early weaning, delayed introduction of complimentary foods, low protein and vitamin A diet and sever/ frequent infection. In Ethiopia the intake of vitamin A is inadequate; especially provision of the vitamin through dietary improvement, food fortification, and supplementation is less. The consumption of vitamin A-rich fruits and vegetables and foods made from roots and tubers is about 24–25 %. Orange fleshed sweet potato is climate smart and food and nutrition sensitive crops. Kocho is the product from Enset, is also climate smart crops. The purpose of this study was to assess nutritional, microbial and sensory properties of complementary food developed from Kocho, Orange fleshed sweet potato and haricot beans. Porridge was developed with different proportion of kocho to haricot bean flour: 90:10, 80:20, 70:30 and 100:0 (control) and orange fleshed sweet potato (15 %) was incorporated. The Nutritional composition of porridge was done by using a method of Association of Official Analytical Chemists, 2000. The beta carotene/Vitamin A content was determined by using High Performance Liquid Chromatography. The total mold and yeast and total plate count for the safety were carried out by using the standard procedure for examining microbial load on the food products. Sensory acceptability of the porridge was evaluated with 30 panelists comprising of mother-children in pair using 5 point hedonic scale. The result of the study showed that the Nutritional composition fulfils the minimum recommended daily allowance for children age between 6–23 months and full fills 65.14 % daily requirement of vitamin A. The microbial analyses of the developed porridge were within the microbiologically accepted limit. All porridge were accepted and liked by the consumers. Thus, based on the finding of this study it was suggested that mothers/caregivers should feed their children haricot bean and orange fleshed sweet potato incorporated porridge.

Keywords: Children, protein-energy malnutrition, VA deficiency

Genetic diversity in anchote (*Coccinia abyssinica* (Lam.) Cogn) using microsatellite markers

ZERIHUN TESHOME MELAKU, MESERET TESEMA TERFA, TEMESGEN MAGULE OLANGO

Hawassa University, College of Agriculture, School of Plant and Horticultural Science, Ethiopia

Anchote (*Coccinia abyssinica* (Lam.) Cogn) is an endemic crop species of Ethiopian origin mainly cultivated for its nutritious tuberous roots and tender leaves. The crop plays an important role in the local diet of rural and peri-urban communities mainly in Western and South Western Ethiopia. Limited molecular marker resources hinderbreeding and genetic studies for improvement, conservation and management of anchote genetic resources. In this study we aimed to (i) measure the genetic diversity of *C. abyssinica* and of its populations; and (ii) describe the genetic structure of populations across the cultivation range in Ethiopia. A total of 45 germplasm accessions collected from Western parts of Ethiopia were studied along with three cultivars of related species in Cucurbitaceae family using 24 microsatellite markers. Results showed high level of genetic diversity in the

anchote accessions. All the analysed loci were highly polymorphic and detected a total of 354 alleles among all population, with an average of 15 alleles per locus. The average genetic diversity, as quantified by the expected heterozygosity, was 0.88 ± 0.06 per locus. Nei's gene diversity index was the highest ($I = 1.93$) for populations

from East Wellega maintained *in situ* in the farmers' field and *ex situ* in Debre Zeit Agricultural Research Center (DZARC). Using discriminant analysis of principal components (DAPC), four clusters including outlier groups were detected. The DAPC analysis indicated that the most closely related populations geographically occurred in close proximity to each other. AMOVA attributed 95 % of the genetic variation to within population and only 4 % to between populations. The results provide important genetic information in *C. abyssinica* to drive improvement, management and conservation decisions efforts.

Keywords: Anchote germplasm, Ethiopia, genetic diversity, genetic structure, microsatellites

Contact Address: Zerihun Teshome Melaku, Hawassa University, College of Agriculture, School of Plant and Horticultural Science, Piazza, 05 Hawassa, Ethiopia, e-mail: zedbezy@gmail.com

Production potentials and technology practices for potato and tomato cultivation in Arsi zone, Ethiopia

Geleta Diriba-Shiferaw[1], Yifru Sisay[2], Tirfe Zegeye[2], Samuel Mezemer[3], Bezawit Seifu[3], Dekeba Moges[3], Samuel Woldeyohanes[4], Anis Dzankovic[5], Bernd Müller[5]

[1]*Arsi University, Dept. of Horticulture and Plant Sciences, Ethiopia*

[2]*Arsi University, Agricultural Economics, Ethiopia*

[3]*Arsi University, Food Science and Postharvest Technology, Ethiopia*

[4]*Arsi University, Dept. of Agribusiness and Value Chain Management, Ethiopia*

[5]*Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Germany*

Vegetable crops have high potential towards food security, local industries, natural resources conservation and market stability. However, many vegetables are untapped resources that can be improved and utilized towards better livelihood of people. Thus, the study was undertaken to assess potato and tomato vegetables production potentials and technology practices of Ziway-Dugda and Tiyo Districts during 2022. Data were collected from 400 households in ten kebeles of both districts and analyzed using SPSS version 22. The study results revealed that the farmers in the study areas produced various crops in addition to tomato and potato and produced average yields of tomatoes (621 q ha^{-1}) and potatoes (46 q ha^{-1}) and got better revenues (116,994 and 41,290 Birr) by selling the two vegetables produced during 2020/21 cropping seasons, respectively. Many farmers in the study areas had potentials and inputs for production of tomato and potato crops. However, some farmers in the study areas had not got the various potentials and resources to be productive in vegetables cultivation. Also many farmers in the study districts had implemented different pre-harvest production practices like cultivation tools and methods, planting spaces, staking of tomato, earthing up of potato, and irrigation practices and rotation cultivation. However, the study results showed that there are unused production practices for tomato and potato cultivation by some farmers. Thus, it is possible to conclude that there are many production potentials, inputs, services, production practices and technologies used by farmers for better vegetables production even though some farmers were not practiced improved production and management technologies that needs future interventions to capacitate them.

Keywords: Farming practices, management strategies, potato, production potentials, Tiyo, tomato, Ziway-Dugda

Tomato production in Ethiopia – gross margin comparison of smallholder tomato farmers

Bernd Müller[1], Anis Dzankovic[1], Sisay Yefru Derbe[2], Gezahegn Nigusse Kelikay[3], Ermias Tesfaye Teferi[4]

[1]*Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Germany*

[2]*Arsi University, Dept. of Agricultural Economics, Ethiopia*

[3]*Hawassa University, School of Nutrition, Food Science and Technology, Ethiopia*

[4]*Bahir Dar University, College of Agriculture and Environmental Sciences, Ethiopia*

Tomato is one of the most important vegetable crops in Ethiopia, both in terms of its economic and nutritional value. It is a major cash crop for smallholder farmers and contributes significantly to household income and food security.The study aims to provide insights into the economic performance of tomato smallholder farming in Ethiopia and inform policies about interventions that can support the growth of the sector. It is imperative to understand available potential resources for vegetable cultivation, and production and management practices and technologies used by farmers in the study districts. With a survey, which was done in 2022 with face-to-face interviews of 1200 selected tomato farmers in three different regions of Ethiopia (Amhara, Oromia and Sidama region), smallholder farmers' characteristics and farm practices, with special emphasis on the production, economic parameters, harvest and storage of tomatoes are mapped.

One important measure of the profitability of tomato production is the gross margin, which is the difference between the total revenue and the total variable costs. A gross margin is an essential tool for farmers to evaluate the profitability of their crops and make informed decisions about production and marketing. This study will compare the gross margin of tomato production and the factors that affect profitability and identify strategies for improving the gross margin of tomato farming in the three mentioned Ethiopian regions. The key output of the research will be to bring the evidence of tomato production gross margins from three different regions, detecting the differences and examining the factors, which lead to those differences in gross margins. The potential users of this study could be policy-makers, advisory services, researchers and tomato producers themselves.

Keywords: Ethiopia, food value chain, gross margin, tomato production

Contact Address: Anis Dzankovic, Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Markgrafenstraße 16, 91746 Weidenbach, Germany, e-mail: anis.dzankovic@hswt.de

Production efficiency of smallholder onion producers in Ethiopia: Stochastic frontier model

Solomon Bizuayehu Wassie[1], Amarech Yitayeh[1], Ermias Tesfaye Teferi[1], Bernd Müller[2]

[1]*Bahir Dar University, Agricultural Economics, Ethiopia*
[2]*Weihenstephan-Triesdorf University of Applied Sciences, HSWT International School, Germany*

Despite the increasing role of onion as a cash crop for farmers, its productivity in Ethiopia ($8.89\,\mathrm{t\,ha^{-1}}$) is far below the world average ($19.32\,\mathrm{t\,ha^{-1}}$). Productivity can be increased either through the introduction of new technologies or by improving production efficiency while using the existing technology. In the context of developing countries like Ethiopia, where resources are limited, it is wise to exhaustively use the potential from the second option. In this regard, as part of a collaborative TOMATO project between Weihenstephan-Triesdorf University of Applied Sciences and Bahirdar University, this study used a stochastic frontier methodology to estimate the production efficiency of onion production among smallholder onion farmers in Ethiopia. The estimation results show that the average technical efficiency among smallholder farmers is 68.5 %, suggesting that there is a substantial inefficiency in onion production. The results suggest that, by operating at full technical efficiency onion producer farmers can, on average, increase production by 31.5 %. The further results demonstrated that the main factors attributing to production inefficiency among smallholders include the age of the household head, livestock ownership, income, and use of improved seed. Specifically, while the age of the household and total livestock holding has a negative and significant effect on inefficiency, the income of the household and the adoption of improved technology affects the efficiency of smallholder onion producers positively and significantly. Overall, the results suggest that there is room for increasing onion production by improving the production efficiency of smallholder farmers through policies that improve access to improved seed, and encourage youths to participate in onion production.

Keywords: Ethiopia, onion production, production efficiency, smallholder farmers

Economic analysis of the local milk value chain in the Kara region

Linanguidaba Bawelima Adjayi, Mikémina Pilo

University of Kara, Dept. of Economics, Togo

This study focuses on the analysis of the local milk value chain in the Kara region of northern Togo. The field survey took place during the month of July 2019 in the selected villages. Simple random selection and reasoned selection was used to select 57 small producers, 30 individuals each for processors, traders, and milk consumers in the study area. The data collected through the semi-structured questionnaires were coded, entered, and analysed using the Kobotoolbox software. The results showed that most of the production link is made up of small producers, illiterate and Fulani. The links of processing and marketing are made up of Fulani women who are mostly married to agro-pastoralists. As for the link of consumption, it consists of men and women, composed of several ethnic groups living in urban areas of the Kara region. From the point of view of interactions between actors, the study shows that the rules governing these relationships are neither contractual nor con- ventional. Compared to the economic analysis, on average throughout the chain, traders have the highest margin (73.5 %) compared to producers (10 %) and processors (16.5 %). Through SWOT analysis, many constraints have been identified along the chain, particularly the lack of organisation of the value chain, the lack of storage and packaging infrastructure. The recommendations formulated for a good organisation of the chain can be summed up in the establishment of an interprofessional organisation, the capacity building of agro breeders to good farming practices to produce milk in quantity and quality, the establishment of storage and conditioning infrastructure at the zone level; and the support of actors in the sector by the public authorities through a possible program.

Keywords: Analysis, Kara region, local milk, value chain

Implementation of rapeseed oil production unit in Tunisia

Asma Koussani

Sotagri, Tunisia

Raps (*Brassica Napus*) is one of the new crops recently introduced in Tunisia due to its benefits, not only for oil, animal feeding or as biodiesel but also for its adaption to climate change.

Tunisia is planning to increase the cultivated area of rapeseed to 140,000 ha from the current 15,000 ha over the next 7 years to boost local supply. The ambitious rapeseed development strategy is being spearheaded by the Tunisian gouverment in partnership with Private Companies.

Tunisia is the largest producer of olive oil outside the EU, and the 4th largest in the world but local supply of the commodity is constrained due to a greater focus on exports. Among the locals, soybean oil is most popular for household consumption while palm oil is not well perceived by consumers and is generally limited to the food manufacturing sector.

As the country is not fully self-reliant on either of these two commodities, it mostly relies on imports and in order to ensure a sufficient local supply of edible oil, UTAP has identified cultivation of rapeseed as a viable alternative to olive oil which is highly sought after in the international market.

Supporting this goal by setting up a startegy with view to improving the profitability of farmers in the various production areas and developing the value chain of this crop is one of the priorities. Also, the transformation of raps into oil and enhancing its secondary outputs should be promoted seems it is one of the major links.

As a result, our project will meet the needs and guarantee an efficient exploitation of this resources by producing high quality rapeseed oil, managing the supply chain from farmers to consumers and will be part in the achievement of the desired goals in termes of local market demand satisfaction and profitability.

Keywords: Local market demand, profitability, raps oil, satisfaction, self-reliant production

Contact Address: Asma Koussani, Sotagri, Le Kef, Tunisia, e-mail: asma_koussani@yahoo.fr

Nourishing futures: Cultivating nutrition and male engagement for healthy childhoods on Likoma Island, Malawi

TIWONGE VANESSA LONGWE

Unilia, Malawi

Malnutrition remains a persistent concern among children under the age of five in Likoma Island, a lakeshore district in northern Malawi, with high stunting levels of 26.6 % despite national reductions in malnutrition rates for young children. Current efforts to raise awareness about proper nutrition among young children lack a gendered approach for effective dissemination.

Comprehensive nutrition education has shown promise in reducing malnutrition. To maximise impact, the project will utilise community radios, proven effective channels for disseminating information, to reach a larger audience in the district. Additionally, the project strives for sustainability by empowering local non-governmental organisations on the Island with nutrition knowledge through proper training. By imparting nutrition knowledge and skills to local non-governmental organisations, the project ensures that the island's community will continue to tackle malnutrition beyond the project's duration. This approach not only builds capacity within the community but also empowers them to address future challenges independently.

The project's holistic approach is designed to break down barriers and inspire a collective effort in prioritising the nutritional needs of children. It also aims to create a positive shift in societal norms, encouraging increased male involvement in child care and nutrition, leading to healthier and happier families. This approach will contribute to a comprehensive reduction of malnutrition among children under five on Likoma Island. Ultimately, the goal is to foster increased male involvement and improved inter-organisational collaboration to prioritise the nutritional needs of children while ensuring sustainability and lay the groundwork for a brighter and healthier future for Likoma Island's youngest generation.

Keywords: Improved nutrition, inter-organisational collaboration, male engagement, sustainability, under-five

Contact Address: Tiwonge Vanessa Longwe, Unilia, Lilongwe, Malawi, e-mail: tiwolongwe1@gmail.com

Aflatoxin management in groundnuts in Malawi

Theresa Manonga

Spring Farms, Malawi

Groundnuts are one of the widely grown legumes in Malawi and they have the potential to contribute to food and income security. However, its production is marred with a lot of challenges and some of these challenges include; delayed planting, diseases like rosette and pests such aphids, planting recycled seed, low plant population and aflatoxin contamination. Aflatoxins contamination makes groundnuts unsafe for consumption and trade. Aflatoxins commonly called 'chuku' are toxins that are produced by fungus that are strains of Asperagillus flavus and Asperagillus parasiticus under suitable conditions during pre or post-harvest activities. Good agronomic practices such as use of resistant varieties, crop protection, insect control and timely planting can reduce pre-harvest aflatoxin contamination and post-harvest contamination can be reduced by proper drying of the groundnuts after harvest, proper storage, transportation, sorting, grading and packaging. It has been observed that Malawi loses 40 % of its export groundnuts due to aflatoxins each year. It is with this background that the study aims at training farmers in producing groundnuts with no aflatoxin or with acceptable aflatoxin levels. The study will explore the use of *Moringa oleifera* leaf extract in the control of aflatoxin in groundnuts. field trials will be conducted in aflatoxin-prone regions, using different application methods of *moringa* extracts on groundnut crops. The aflatoxin levels will be quantified at various stages of growth and post-harvest storage to determine the efficiency of *Moringa* in reducing aflatoxin contamination. If proven effective, the integration of moringa-based interventions in groundnut production can significantly improve food safety, protect human health, and enhance economic outcomes for farmers. The study will contribute to the knowledge of harnessing natural plant-based solutions to address aflatoxin contamination in groundnuts. The findings will have an impact on food safety, public health, sustainable agriculture, trade for Malawi and promote the adoption of nature-inspired strategies in the fight against aflatoxins.

Keywords: Aflatoxin, contamination, groundnuts, management

Contact Address: Theresa Manonga, Spring Farms, Lilongwe, Malawi, e-mail: theresama2@gmail.com

Improving the olive production in Tunisia: Virtual and practical pruning training

Amira Najjar

Entrepreneur, Tunisia

Olive cultivation holds immense economic and cultural significance in Tunisia, with olive oil production being a pillar of the nation's agricultural sector. Pruning is a critical horticultural practice that directly influences olive tree growth, fruit production, and overall orchard health. However suboptimal pruning can lead to reduced yields, and increased susceptibility to diseases. Moreover, the olive industry faces significant challenges related to the shortage of skilled labour, limited knowledge, and inadequate access to specialised training. To address these issues, this study project proposes the implementation of a Virtual Pruning Training (VPT) programme designed to empower Tunisian olive growers.

Using modern technology, the training aims to provide a scalable and cost-effective solution for disseminating pruning expertise to olive farmers or workers across the country. It would be developed in close collaboration with olive growers' associations, and Tunisian agricultural research institutions to ensure its relevance to the local context. The programme offers face-to-face or online conferences with virtual practice features and interactive 3D tree simulations together with organised practical workshops in field. The VPT focuses on understanding olive value chain (VC) in upstream, then identifying appropriate pruning times based on tree growth patterns, recognising different pruning techniques virtually and practically, and the impact of pruning on fruit production and tree health. The VPT programme includes virtual practice using 3D models collected from real-life case studies, showcasing successful pruning practices and their subsequent positive effects on olive production. These Interactive elements enable participants to simulate pruning scenarios, providing hands-on experience in a virtual environment.

By promoting sustainable and efficient pruning practices, the VPT programme aims to minimise production losses and increase the economic viability of olive farming in Tunisia. The success of the VPT project would be assessed through pre- and post-training evaluations as well as feedback from participants and stakeholders. The VPT for olive trees in the Tunisian context represents a transformative step towards elevating the country's olive VC. By empowering farmers with knowledge and practical skills, the VPT aims to foster sustainable agricultural practices, secure olive production, and preserve Tunisia's rich olive heritage for future generations.

Contact Address: Amira Najjar, Entrepreneur, 2,Greece street, 1110 Mornaguia, Tunisia, e-mail: amira.najjar.inat@gmail.com

ID 1002

Establishing an experimental farm for educational services to promote the value chain of the olive-growing sector in southern Tunisia

Souha Neili Ep Essid

Otmc Consulting, Tunisia

Tunisia has become the North African olive grove par excellence. In fact, excluding the coun-tries of the European Union, Tunisia is the world's largest producer of olive oil and the lead-ing exporter, ranking second in the world in terms of surface area used for olive production. Despite this significant potential, the olive-growing sector faces a number of constraints. The average productivity of olive production in Tunisia is low, fluctuating and falling. In terms of yield per hectare, Tunisia ranks last among nine producer countries in the European Union and the Middle East-North Africa region. In fact, the high percentage of poorly maintained olive trees is a major handicap for Tunisian olive growing. In order to remedy this situation and improve the level and the stability of yields to strengthen the economic and social conditions of the most disadvantaged operator (the farmer) in the olive value chain in southern Tu-nisia, several recommendations can be suggested. One of the ways to achieve this is to extend the use of drip irrigation methods and to improve the Know-How in good practices. Moreover, establishing a project in the form of an experimental plot dedicated to educational services remains a fruitful and significant decision. In fact, our project involves an educational farm consisting of a plot of olive trees examining different irrigation techniques. In this olive grove, we will practice experimentally tested cultivation techniques. Our farm will also have a tasting room for olive oil tasting courses and a children's area where they can take part in activities in the form of workshops on different themes (the history of olive oil, the olive tree and science) to foster the love of the olive tree. In addition, we will offer a table d'hôte of home cooking prepared with local products. Finally, our project will be planted in Menzel El Habib, a rural area in the governorate of Gabes characterised by a strategic geographical location.

Keywords: Experimental parcel, know-how, olive sector in Tunisia, promote the olive value chain

Contact Address: Souha Neili Ep Essid, Otmc Consulting, Gabès, Tunisia, e-mail: nailisouha1@gmail.com

Promotion of biofortified crops through establishing production & processing demonstration sites for vitamin A maize in Gombe State, Nigeria

Dolapo Natalie Omokanjuola

Harvest Plus Nigeria, Nigeria

Maize stands as Nigeria's most consumed staple food; however, smallholder farmers continue to grapple with low agricultural productivity, impacting their income and access to nutritious foods. This inaccessibility to nutritious foods contributes to micronutrient deficiency with Vitamin A deficiency (VAD) being a prevalent issue especially among young children and women of reproductive age. While Nigeria cultivates yellow and white maize extensively, the recent introduction of Vitamin A maize, commonly known as orange maize, holds promise as a climate and nutrition-smart crop. It exhibits high yield, disease resistance, drought tolerance, and a higher Vitamin A content. Though its adoption is gradually increasing in states like Kaduna, Kano, and Jigawa, Gombe State lags behind.This study project aims to enhance the productivity of smallholder farmers and reduce Vitamin A deficiency among children and pregnant women in two Local Government Areas in Gombe State through the promotion of Vitamin A maize. Gombe State is characterised by a high poverty level, vulnerable groups, and has become home to internally displaced persons due to the insurgency in the Northeastern part of Nigeria. The promotion project will explore two approaches: establishing Vitamin A maize production demo sites and processing demo sites. The production demo sites will serve as learning plots, helping farmers adopt Vitamin A maize, resulting in a significant 50 % increase in their yield compared to conventional maize breeds. On the other hand, the processing demo sites (nutrition corners) will be set up at Primary Health Care Centers, providing knowledge to women and caregivers on integrating Vitamin A maize into their household consumption to fulfil their daily Vitamin A needs. Ultimately, this biofortification promotion will enhance food availability, accessibility, and utilisation in Gombe State.

Keywords: Biofortified crops, Gombe State, smallholder farmers, vitamin A deficiency, vitamin A maize

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Contact Address: Dolapo Natalie Omokanjuola, Harvest Plus Nigeria, Kano, Nigeria, e-mail: domokanjuola@gmail.com

ID 1004

Promotion of entrepreneurial innovations in the village poultry value chain for sustainable rural development

Diderline Manfouo Tchoupou

Sopead Conseil Sarl, Cameroon

Village poultry farming plays an undeniable socioeconomic role in most rural households (savings, animal protein intake essential for a good balanced diet, land fertilisation through the use of droppings, eggs are also used in rituals and in the traditional pharmacopoeia etc.). However, many small farms in the value chain of village chickens earn quite low incomes with low productivity and have never managed to integrate into the economic circuits of the agrofood sector. Despite its importance, the fundamentals of this breeding are not mastered by the breeders, which results in low productivity, significant and sometimes total losses of staff during epidemics, a weak technical supervision system, the lack of knowledge techniques and access to training. Thus, this project aims to implement innovations in the value chain of village poultry that have contributed to sustainable rural development through increased productivity and improved incomes of small farms, as well as the creation of decent jobs. More requested will be: Ensure the training of 2,000 breeders on Good farming practices, including at least 50 % of young people and 35 % of women, Ensure the training of 3,000 breeders and other actors in farmer Business school » and in organisational development, developing entrepreneurial business models and providing value chain actors, monitoring the application of learning, organising awareness caravans and exchange visits. Achieving these objectives will require the use of participatory approaches to sustainable development and the organisation of "farms-schools-peasants". The main activities of the project will be: the establishment of a management and coordination unit, Establishment of a training system, Development of planning and reporting tools, Training of producers on Good Breeding Practices, Farmer Business School and in Organisational Development, Organisation of caravans and Monitoring of activities.

Keywords: Autonomy, entrepreneurship, innovation, professionalisation, small producers, sustainable development, village poultry farming

Contact Address: Diderline Manfouo Tchoupou, Sopead Conseil Sarl, Dschang, Cameroon, e-mail: diderline@yahoo.fr

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