Tropentag 2024

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

Explore opportunities... for managing natural resources and a better life for all

Book of abstracts

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Preface

Tropentag is an annual international conference on research in tropical and subtropical agriculture, natural resource management and rural development. It is Europe's largest and most diverse interdisciplinary conference, bringing together researchers, academics, and professionals from various fields and 80 nations worldwide. The theme of the Tropentag 2024, *'Explore opportunities ... for managing natural resources and a better life for all'*, is not just a theme but a call to action. Organised by the BOKU University (University of Natural Resources and Life Sciences Vienna), Austria, in cooperation with the Council for Tropical and Subtropical Research (ATSAF e.V.), this conference will take place from 10. - 13. September 2024. After 2016, the trans- and interdisciplinary conference 'Tropentag' occurs at BOKU University Campus 'Türkenschanze' in Vienna's 19. district.

At Tropentag 2024, we will address upcoming topics in rural development, sustainable resource management, and global poverty reduction. These include the transformation in agriculture and food systems, food sovereignty, climate change adaptation, environmental protection, social and technological innovations, especially for the implementation of the SDGs, and gender-based structural inequalities in natural resource management. Your expertise and contribution are welcome and crucial in addressing these pressing issues. You are all an integral part of our mission to explore opportunities for a better future. The topics below collectively contribute in 70 sessions to the conference's overarching aim of exploring opportunities to manage natural resources sustainably and improve the quality of life for all:

- Agroecology and sustainable resource management practices
- Livestock management and human well-being
- Food systems for sustainable diets and health
- Sustainable water and fisheries management
- Climate change adaptation and resilience
- Forestry, environmental conservation and ecosystem services
- Gender and intersectional perspectives in the governance of natural resources
- Multiple crises: political, institutional and economic structures and challenges
- Social and technological innovations for implementing the sustainable development goals (SDGs)

The Tropentag traditionally offers young scientists a platform to present and discuss their research with renowned scientists and experts.

This year, we received over 850 submissions. Participants will give about 500 oral and poster presentations in person or online. In addition, we received the commitment of eight important keynote and invited speakers to address the current topics of the conference and discuss them broadly. We organised 110 oral presentations grouped into 26 scientific sessions, 35 face-to-face poster sessions, and 10 online poster sessions. These are now available in this book of abstracts. There will also be 24 pre-conference and 7 post-conference workshops, broadly engaging with this year's conference theme.

We want to thank all the participants, especially our invited speakers, for their scientific contributions and our colleagues on the TT24 scientific committee for reviewing the abstracts and chairing the oral and poster sessions. We especially want to thank Eric Tielkes and his ATSAF team for their invaluable support and guidance in making this outstanding and unique event possible. Special thanks to the BOKU University administration staff and students for helping organise this conference and our international student reporters for their refreshing activities. Special thanks to our longstanding list of donors for their generous financial and in-kind support; TT24 would not have been possible without their contribution.

We welcome you to Vienna and wish you an inspiring and enriching conference.

On behalf of the Tropentag 2024 organising team:

Andreas Melcher, Katharina Keiblinger, Stefan Strohmeier, Andreas Bauer, Julia Männle and Eric Tielkes.

Vienna, September 2024

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The role of science and innovation in delivering the SDG – nature based solutions with trees

Anja Gassner

The Center for International Forestry Research and World Agroforestry, CIFOR-ICRAF Director Europe, Germany

The year 2023 "smashed" the record for the hottest year by a huge margin, providing "dramatic testimony" of how climate is threatening human and planetary health. We are dangerously close to – and in some cases, crossing - catastrophic ecological tipping points accompanied by major shifts in the global economy and an unacceptable increase in inequality. But it is not too late. Healthy agricultural and forested landscapes have a key role in changing these trends. They can deliver one-third of the climate solution - soil accounts for one-third of the global carbon stock and forests net-absorb 1.5 times more CO₂ than the US emits annually. Crucially, they can do that while enhancing the biodiversity and soils that underpin livelihoods and sustainable food production. While there are still unknowns that will benefit from science, we don't have the time to wait. We need to leverage cutting-edge research to drive tangible impact for communities and ecosystems. We need to implement projects around known solutions while embedding research to understand how to scale. The biophysical evidence is mostly there, the bigger unknown is the human side - people's behaviour. Research to understand how and why people can become change makers, what holds them back is crucial. We need to combine scientific expertise and analytical skills with exceptional communication skills to bridge gaps between research, policy, and practical implementation and we need to translate complex scientific concepts into compelling narratives for diverse stakeholders.

Contact Address: Anja Gassner, The Center for International Forestry Research and World Agroforestry, CIFOR-ICRAF Director Europe, Bonn, Germany, e-mail: A.Gassner@cifor-icraf.org

Can biodiversity conservation provide a better life for conservation labourers?

Lerato Thakholi

Wageningen University and Research, Sociology of Development and Change Group, *The Netherlands*

Political ecologists have convincingly shown that biodiversity conservation is yet another avenue for capitalisms expansion through -for instance- the commodification of wildlife, ecotourism and bioprospecting. Advancing these earlier observations, scholars are beginning to systematically analyse the role of workers in creating surplus value within conservation. Often silent in these analysis, however, is a critical look of how biodiversity conservation exploits workers racial and gender differences to accumulate value. Borrowing from feminist scholars conceptualisation of social reproduction and theorisations of racial capitalism I critically analyse the conditions of waged and unwaged conservation labourers in southern Africa's conservation provide a better life for conservation labourers?

Contact Address: Lerato Thakholi, Wageningen University and Research, Sociology of Development and Change Group, Wageningen, The Netherlands, e-mail: lerato.thakholi@wur.nl

Rainfed agriculture – an essential pillar of sustainable and climate resilient food system

Jennie Barron

Swedish University of Agricultural Sciences, Dept. of Soil and Environment, Sweden

Food systems need to become more productive and nutritious for a growing global population, whilst being environmentally sound, and withstanding climate change. Rainfed agriculture, today providing more than 60 % food, feed and fodder on crop and grazing and is therefore a critical production system that holds large potential to sustainably intensify globally and locally, but often lacking attention and investments. In this talk I will share analysis of 3 case studies from El Salvador, India, and Ethiopia, developed in partnership with SIWI, CRS, ICRISAT and partners, documenting rainfed systems intensification and scaling through soil and water management. The presentation will share area of data and knowledge limitations, and propose potentially essential topics of knowledge development for future acceleration of soil and agricultural water management in rainfed systems

Reference report Barron, Jennie, Anna Tengberg (eds). 2023. Rainfed systems intensification and scaling of water and soil management: four case studies of development in family farming. Technical Report. Swedish University of Agricultural Sciences (SLU) Uppsala DOI: https://doi.org/10.54612/a.4nbusqmc4l

Contact Address: Jennie Barron, Swedish University of Agricultural Sciences, Dept. of Soil and Environment, Uppsala, Sweden, e-mail: jennie.barron@slu.se

Beyond sustainable development in the era of planetary crises: Challenges and insights from Latin America towards deep green transformation

Johannes Waldmüller

University of Vienna, Dept. of Political Science, Austria

In the wake of accelerated global climate change and expanding civilisational crises, in my talk, I will address how ubiquitous Northern transitions to greener and more sustainable economies and lifestyles are taken up by diverse groups and societies in resource-rich regions of the global South.

To do so, I draw from my longstanding close engagement with Latin America, particularly its Pacific-Andean region. In this context, I will briefly outline the major climate change impact, translated into social, economic and political dimensions, this region is already facing and what can be learned from it elsewhere.

Looking then beyond predominant market-driven approaches and "liberal" perceptions of sustainability, I aim to describe the relevance of diverging understandings and conceptions of relevant climate action, adaptation and mitigation, such as Indigenous and Black-Andean "sustainability from below" through feminist readings of "socioecological care and reproduction".

Such understandings underpin the worldwide growing number of implemented Earth jurisprudence (rights of nature), but also discussions about *Buen Vivir/Vivir Bien* (good living), based on a different ontological status and biocentric conception attributed to vital ecosystems. Furthermore, they call for a shifted and embodied engagement with our sustaining surroundings through the acquisition of a transformed skills set, focused on encompassing care cultures. Altogether, a more encompassing conception of green transitions becomes identifiable by connecting key insights from the global North and South, which I termed "deep green transformation" (Waldmüller 2024 - DOI: 10.1080/17449626.2024.2379324) and which represents the overall backdrop to my keynote intervention.

Contact Address: Johannes Waldmüller, University of Vienna, Dept. of Political Science, Vienna, Austria, e-mail: johannes.waldmueller@univie.ac.at

Agroecology and living well: Towards agri-food systems within the 'doughnut'

Jонаnna Jacobi ETH Zurich, Agreocological Transitions, Switzerland

Environmental sustainability and social justice are intrinsically linked: SDG1 aims to end poverty, SDG 2 aims to end hunger, recognising that both are only possible while conserving natural resources. However, food insecurity is on the rise again since 2014, and the Human Development Index (composed of life expectancy, education and income) is decreasing since 2019. A key criticism is the persistence of the economic growth paradigm, which still underpins the mainstream idea of progress by perpetuating overconsumption and prioritising luxury tastes over basic needs. Oxford economist Kate Raworth's 'doughnut' framework depicts an economy that respects the planetary boundaries while achieving basic needs coverage for all, meaning that certain sectors grow and expand, while others shrink or change significantly. If human wellbeing is understood in a multidimensional way, encompassing not only a material dimension, but also a cognitive dimension and a relational dimension, then it becomes clear that the quality of 'development' is as important as the quantity. This is particularly true for agri-food systems: As we already produce enough food for everyone but are unable to end hunger, the question should not be how much can be produced, but how much is needed (and of what, and where and by whom). Applying post-growth principles to agri-food systems requires a paradigm shift from efficiency to sufficiency, from extraction to regeneration, from accumulation to distribution, from private enclosure to commons, and from control to care. These principles are compatible with agroecological principles as formulated by social movements around the world, and, more recently, also by the FAO and HLPE. For example, agroecology contributes to regeneration by reducing external inputs and increasing agrobiodiversity. By strengthening the autonomy of farmers and their participation in decision-making, agroecology supports distributive justice, land, water, food and seed commons, and care over a technoscientific idea of external control. The plethora of agroecology examples around the world often have in common that they reconnect producers and consumers in more direct relationships by-passing concentrated power in the food system or finding new working models related to sufficiency such as the "halffarmer, half X" lifestyle. For these examples to scale up, out, and deep, a concerted effort is needed at all societal levels beyond a simplistic economic growth paradigm.

Contact Address: Johanna Jacobi, ETH Zurich, Agreocological Transitions, Zurich, Switzerland, e-mail: johanna.jacobi@usys.ethz.ch

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Co-creation of agroecological practices combinations in agroecology living labs

Diego Cerrudo¹, Mehreteab Tesfai², Hycenth Tim Ndah³, Ruphine Batumike⁴, Precillia Ijang Tata Ngome⁵, Jules Ntamwira⁶, Vicky Ruganzu⁷, Innocent Kirayi Nsengimana⁸, Marie-Chantal Niyuhire⁹, Isaac Balume¹⁰, Wivine Munyahali¹¹

¹CIRAD, UPR-AIDA, France

²Norwegian Institute of Bioeconomy Research, Division of Environment and Natural Resources, Dept. of Soil and Land use, Norway

³University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany

⁴IITA, Research and Adaptation Team, DR Congo

⁵National Institute of Agricultural Research Development (IRAD), Cameroon

⁶INERA, Banana Research Program, DR Congo

⁷*Rwanda Agriculture and Animal Resources Development Board (RAB), Rwanda* ⁸*APDIK, DR Congo*

⁹ISABU, Land management and Agroecology, Burundi

¹⁰ETH Zurich, Sustainable Agroecosystems, Switzerland

¹¹Catholic University of Bukavu, Fac. of Agronomy, DR Congo

Agroecology offers pathways to increase productivity and build resilience to socio-ecological, economic, and climate shocks by delivering holistic solutions to complex challenges in agriculture and food systems. However, we lack co-designed, co-tested, and context-specific agroecological practices (AEP) to guide a transition. In response to this, the CANALLS project is set to drive agroecological transitions in the humid tropics of Central and Eastern Africa via multi-actor transdisciplinary Agroecology Living Labs (ALLs). Central to the ALLs is co-creation through the active engagement of diverse stakeholders, including farmers, experts, governmental agencies, NGOs, the private sector, and civil society. In CANALLS, co-creation focuses on codesigning combinations of AEPs to address the key challenges encountered by farmers and other stakeholders along the value chain.

Our co-creation framework follows a structured 4-step cycle: 1) identification and comprehension of challenges; 2) mapping, prototyping, and prioritising AEPs; 3) evaluation of AEP combinations in real-life settings; and 4) assessment of outcomes and formulation of scaling strategies and/ or plans for subsequent co-creation. Co-creation activities commenced with two workshops in 6 ALLs, resulting in the identification of key challenges and the prioritisation of 2–4 AEPs per ALL. The AEPs included biopesticide measures, alterna-

Contact Address: Diego Cerrudo, CIRAD, UPR-AIDA, Ta B 115/02 - Avenue Agropolis, 34398 Montpellier, France, e-mail: diego.cerrudo@cirad.fr

tive sources to soil fertility improvements, erosion control techniques, and improved shade management in agroforestry systems. Once the AEPs were comapped, project partners, together with ALLs stakeholders, conducted field visits to prototype farmer-led experiments on cocoa systems in Cameroon, cassava in Rwanda, maize-legume intercropping in Burundi, and coffee and rice fields in the Democratic Republic of Congo.

Key lessons learned in the co-creation process and establishment of ALLs are: 1) stakeholders showed high interest in agroecology and commitment to participate actively in the project; 2) the bottom-up approach in co-creation brought new ideas and concepts while co-defining the key challenges in agroecology; and 3) each ALL is unique and therefore the design, implementation, and evaluation of AEPs must be adapted to the local context.

Keywords: Agroecological practices, agroecology living labs, Central and Eastern Africa, co-creation

Measuring agroecology and its performance: Generating evidence to scale up agroecological transitions

BEATRICE ADOYO¹, ALEX THOMSON², MATTHIAS GECK¹ ¹World Agroforestry Center (ICRAF), Agroecology, Kenya ²Statistics for Sustainable Development (Stats4SD), United Kingdom

Agroecology is gaining momentum as a promising approach to address food system challenges holistically. However, its advancement depends on the availability of datadriven evidence regarding its performance across various dimensions, including agricultural productivity, ecological integrity, socio-economic well-being, and soil health. To address the gap in evidence-based advocacy for agroecological transitions, the Measuring Agroecology and its Performance (MAP) project customized and applied the FAO's Tool for Agroecological Performance (TAPE) on 839 farms across four countries (Benin, Ethiopia, Kenya, and Madagascar) to: i) Provide evidence of progress towards agroecological transition; ii) Assess the multidimensional performance of agroecology; and iii) Tailor the TAPE tool to assess the contribution of agroecology to soil health. This research was conducted within the framework of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)'s Soil Protection and Rehabilitation for Food Security (ProSoil) project sites, where sustainable farming practices have been implemented since 2015, and comparison farms which are not direct beneficiaries of ProSoil activities. TAPE results show that households actively participating in ProSoil activities have significantly (p < 0.001) higher degrees of agroecological integration across all the ten elements of agroecology than comparison farms. The difference is particularly pronounced for the agroecology element on co-creation and sharing of knowledge and is fairly consistent across the four countries. The level of agroecological integration correlates positively with environmental performance parameters (agrobiodiversity and soil health), economic performance (income and productivity), as well as with dietary diversity and food security. Limited effects were found on Agroecology's contribution to social parameters like women's and youth empowerment. The MAP project further enabled two critical innovations to TAPE: a more robust soil health assessment as well as a novel data management platform. Both of these innovations will be available for all future TAPE users, considerably improving the value and usability of the tool. Finally, through deliberate stakeholder engagements, the MAP project enhanced awareness of and capacities on holistic performance assessment of agrifood systems and agroecology among key actors in the four partner countries and beyond.

Keywords: Agroecology, multidimensional, performance, soil health

Contact Address: Beatrice Adoyo, World Agroforestry Center (ICRAF), Agroecology, Nairobi, Kenya, e-mail: b.adoyo@cifor-icraf.org

Ex-ante evaluation of integrated soil fertility management as a sustainable intensification practice: A probabilistic modelling approach

Dorcas Sanginga Alame¹, Cory Whitney¹, Javier Miranda², Peter Asare-Nuamah³, Janina Dierks¹, Eike Luedeling¹

¹University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany ²University of Bonn, Inst. for Food and Resource Economics (ILR), Germany ³University of Bonn, Center for Development Research (ZEF), Germany

Northern Ghana's agricultural productivity is declining due to soil degradation resulting from the use of agricultural practices that are not locally adapted. This poses a significant threat to local food security and rural livelihoods. Strategies to address this productivity decline focus either on extension or on intensification of agricultural land, yet both options are constrained by land scarcity and low technology adoption rates, respectively. Farming practices with the potential to increase productivity without requiring additional land are available, yet their effectiveness varies depending on the local context. Integrated Soil Fertility Management (ISFM) holds promise as a sustainable intensification option, especially in smallholder farming systems. However, despite the widespread promotion of ISFM in the region, its adoption remains inadequate. Furthermore, the extent of its contribution to sustainable land management and its potential to foster sustainable business models remains largely unexplored. To address this gap, the proposed study implements an ex-ante evaluation of ISFM on sustainability-related outcomes. We operationalize our analysis using a probabilistic modelling approach to simulate the impacts of ISFM in maize-soybean agricultural systems. Through collaborative efforts, engagement with local experts, and survey data, our approach allows simulating the costs, benefits, and risks associated with various ISFM components. Using a decision analysis approach, we run Monte Carlo simulations to generate plausible distributions of intended economic outcomes of ISFM. Further, we applied a sensitivity analysis using Projection to Latent Structures (PLS) regression, which revealed variables that affect the outcome distribution of the business model. We also computed the Expected Value of Perfect Information (EVPI) to determine the monetary value of perfect information on specific variables. The outputs of this study include valuable insights of a sustainable business model of ISFM providing evidence-based models to support adoption and policy interventions for the benefit of local farming communities and the region. An additional advantage of our approach is its flexibility to assess other agricultural practices addressing soil degradation.

Keywords: Decision analysis, Monte Carlo simulation, participatory research, sustainable land management

Contact Address: Dorcas Sanginga Alame, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Auf dem hügel 6, 53121 Bonn, Germany, e-mail: alame@uni-bonn.de

Exploring the impacts and drivers of agro-ecological interventions on managing resources: A case of vegetable production system in Ethiopia

Yidnekachew Zewde, Ralph Roothaert, Wubetu Legesse

World Vegetable Center, Ethiopia

The misuse and abuse of chemical inputs such as fertilisers and pesticides are mostly pronounced in the vegetable sector. To this end, various studies advocate for a sustainable production system that promotes the adoption of agro-ecological practices (AEPs) to enhance the health of people and environment. This paper examines the impacts and drivers of adopting a wide range of AEPs in three districts of Ethiopia. The findings from the study show that capacity development and awareness creation efforts significantly enhanced the perception and uptake of AEPs. The most widely adopted AEPs are soil health interventions, bio-fertilisation, integrated pest management and use of improved seed varieties. The main constraints of adopting AEPs include cost of adoption, ease of access, agronomic requirements, effectiveness of AEPs relative to conventional inputs, scale of production, skills needed for adoption, enabling environment and incentive mechanisms. A comparative costbenefit-analysis shows that the adoption of AEPs helped farmers to reduce the use of conventional inputs (chemical fertiliser and pesticide) by more than 15%. Therefore, AEPs have huge resource-conserving and cost-reducing implications for small-holder farmers. Moreover, a Poisson regression analysis on the determinants of adoption indicates that factors such as age, gender, level of education, farming experience, availability of agrological inputs, farm size, access to training, and proximity to market are important determinants AEPs adoption. However, the market fails to differentiate and value vegetables produced in conventional and regenerative ways. This in fact acts as a huge disincentive for farmers to adopt AEPs and requires institutional and market level interventions. In nutshell, efforts to promote the adoption of AEPs should focus on maximising their impacts coupled with efforts to enhance the enabling environment and policy landscape.

Keywords: Agro-ecology, conventional production, cost-reducing, enabling environment, impacts, resource-conserving, sustainable production system

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

Cultivating change with agroecology and organic agriculture in the tropics - bridging science and policy

Lauren Dietemann¹, Beate Huber², Laura Kemper¹

¹*Research Institute of Organic Agriculture, Dept. of Extension, Training and Communication, Switzerland*

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

Despite the technological advances in food systems since the green revolution, current global agricultural and food systems are not meeting the world's needs. Although food availability has increased substantially, the number of people suffering from hunger and malnutrition has remained steady in the last 40 years, coupled with a surge in obesity and diet-related diseases. Additionally, current food systems have contributed to extensive deterioration of land, water, and ecosystems; depletion of biodiversity; and enduring livelihood pressures for farmers. Nowhere are such challenges more evident than in the tropics, where disproportionate food insecurity, malnutrition and impacts of climate change pose significant threats. This myriad of challenges in current food production systems is projected to worsen if we continue with "business as usual" due to the increasing impacts of climate change, demographic shifts, political instability, conflicts, and heightened demands on natural resources. To address these pressing issues, it is imperative to explore alternative approaches that show promise in transforming food systems and achieving the Sustainable Development Goals. In this context, agroecology and organic (AE/O) agriculture present promising alternatives supported by a growing body of evidence. AE/o systems show promise in achieving yields and incomes that are on par with conventional. In fact, AE/O systems have been shown to improve household income and livelihood resilience compared to conventional in the tropics. The hidden costs of the current global food system amount to around 10 percent of global GDP. The transition to AE/O systems offers a pathway to lower costs to the public by increasing climate adaptation and mitigation, increasing resilience to external shocks, improving food security and nutrition and lowering exposure to harmful pesticides. Thus, investments towards AE/O are not only a moral imperative but an economic win. Despite notable progress, a transition towards sustainable food systems requires increased attention, understanding, and political action. Transition to AE/O systems requires, for example. long-term funding models that prioritise a holistic approach, and value chain development that supports fair pricing and strengthens the connection between consumers and farmers, and improved access to farmers' organisations, capacity development and market access.

Keywords: Climate change adaptation, food security, human health, organic agriculture

Contact Address: Lauren Dietemann, Research Institute of Organic Agriculture, Dept. of Extension, Training and Communication, Ackerstrasse 113, 5070 Frick, Switzerland, e-mail: lauren.dietemann@fibl.org

Burning of maize crop residues and weeds leads to major losses of C, N, P and K

A. SIGRUN DAHLIN¹, V. HUNG DO², V. THACH NGUYEN², INGRID ÖBORN¹ ¹Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden ²World Agroforestry (ICRAF), Vietnam

Carbon and plant nutrient loss from agricultural land lead to loss of soil fertility and to greenhouse gas emissions. Such losses are known to occur during burning of crop residues, commonly practised to control weeds, pests and diseases. However, the extent of the losses are often not known, but the knowledge is needed to assess potential effects of changing management practices. This study reports two trials aiming to quantify the losses of carbon, nitrogen, phosphorus and potassium under the dominating practices of smallholder farmers in Son La province, Vietnam.

A survey showed that fields were burnt shortly before planting (37%), shortly after harvest (37%) or both (26%), and that the plant matter was either heaped before burning or burnt in its original position. We thus carried out two trials, in May and November 2020. A level field of clay soil was smoothed to provide a semi-glossy surface for the trial, with 4 replicates per treatment randomised to plots. Portions of maize residues and weeds, representing the proportions of these in the field, were arranged in heaps or scattered across the plot areas. After burning, the ashes were collected using soft brush and spade. Plant matter portions were also burnt in aluminium basins, serving as reference where no ash could be mixed with the soil. Subsamples of plant material and ash were analysed for carbon, nitrogen, phosphorus, potassium and dry matter.

Almost all carbon of the plant material was lost during burning. Most (86–96%) of the nitrogen was lost, with lowest losses from scattered material. Phosphorus losses were on average 14% in May and 27% in November, without treatment differences. More potassium was lost in May (61%) than in November (18%), and more from heaps (49%) than from scattered and reference material (35%).

The nutrients lost (approx. 30 kg nitrogen, 1 kg phosphorus and 30 kg potassium per hectare) correspond to large amounts of mineral fertiliser or manure and thus economic values, and the carbon loss accelerates loss of soil organic carbon and its benefits. This has long-term implications for the functioning of the soils and the farmers' livelihoods.

Keywords: Carbon loss, crop residue management, field burning

Contact Address: A. Sigrun Dahlin, Swedish University of Agricultural Sciences, Crop Production Ecology, Uppsala, Sweden, e-mail: sigrun.dahlin@slu.se

The use of maggot fly larvae as biofertiliser

NAIMA BENKENANA, RACHAD HAMZAOUI, MOUHAMED ABEDESSAMIE Mentouri Constantine 1 University, Lab. of Biosystematics and Ecology of Arthropods, Algeria

Insect flour can be used as a fertiliser to enrich the soil's fertility with essential nutrients such as nitrogen, phosphorus, and potassium. The experiments were carried out in the Constantine region of Algeria. The results of our experiments show that this type of fertiliser can improve soil fertility and support plant growth. The organic waste was collected from slaughterhouses and placed in a cage to attract flies. After half an hour, the Calliphoridae (*Calliphora vomitoria, Calliphora subalpina, Lucilia sericata,* and *Chrysomya albiceps*) arrive to lay their eggs. Once the eggs hatch (after two days), the larvae feed on the waste up to the third instar. The harvested maggots were separated from uneaten organic waste and kept frozen. After drying the maggots in the laboratory, they were ground in a blender to obtain maggot powder (flour), which is used as a natural fertiliser. Lentils, beans, and other plants were subjected to investigation by using this biofertiliser. After 15 days of soil treatments, there is a direct influence on the size and colour of the plants and also on the number of branches and leaves.

Using maggot powder in agriculture is a major step towards more sustainable and efficient practices. Incorporating such a new techniques into the traceability of agricultural and agri-food products is recommended.

Keywords: Beans, constantine, fertiliser, lentils, maggot, sustainable

Contact Address: Naima Benkenana, University Constantine 1 Frères Mentouri, Lab. of Biosystematics and Ecology of Arthropods, Dept. of Animal Biology, Constantine, 25000 Elkhroub, Algeria, e-mail: benkenanan@yahoo.co.nz

Empowering smallholder olive growers in northwest Tunisia through an agroecological business model

Rihab Mejri¹, Mohamed Zied Dhraief¹, Asma Souissi², Hassen Ouerghemmi², Boubaker Dhehibi², Meriem Oueslati¹, Aymen Frija², Ali M.Oumer², Mahdi Fendri³, Ajmi Larbi³

¹*The National Institute of Agronomic Research (INRAT), The Rural Economy Laboratory (LER), Tunisia*

²*International Center for Agricultural Research in the Dry Areas (ICARDA), Tunisia* ³*Olive Institute, Specialized Unit of Tunis, Tunisia*

Olive cultivation is the most important agroecosystem in the Mediterranean basin. This agroecosystem is facing tremendous challenges, including climate change, loss of biodiversity, environmental pollution and resource degradation, as well as increasing price volatility with harmful implications for farmers' incomes, livelihoods, and rural development. Agroecology is considered actually as the mainstream model for transforming agriculture toward more sustainable and resilient agri-food systems within the given economic and political context. This study aims to conduct an agroecological assessment of the current business model of the olive growers and to develop an upgraded one integrating the agroecological practices and principles in northwest Tunisia. An inclusive and participative approach based on workshops with the main stakeholders in the olive oil value chain was conducted. In addition, a business model canvas (BMC), followed by the application of the Business Agroecology Criteria Tool (B-ACT) was used.

The agroecological assessment results show that six principles specifically, co-creation of knowledge, social value and diets, fairness, connectivity, land and natural resource governance, and participation are integrated within the existing BMC, but hold significant promise for enhancement within an up-graded BMC. Conversely, four principles (recycling, input reduction, animal health, and biodiversity) demonstrate the strongest levels of alignment with agroecological transition in the current BMC. The upgraded BMC represents a transformative vision addressing the constraints of the current model, emphasising collaborative endeavours, agroecological practices, and strategic partnerships, as well as an accelerator to catalyze agroecological transitions. It focuses on economic diversification, niche market penetration, and heritage preservation. The establishment of an Olive Growers' Association is geared towards unifying and empowering olive growers, fostering collaboration and access to resources, knowledge exchange, collective decision-making, and colearning in sustainable food systems. Additionally, the adoption of agroe-

Contact Address: Rihab Mejri, The National Institute of Agronomic Research (INRAT), The Rural Economy Laboratory (LER), Tunis, Tunisia, e-mail: mejri_rihab@ymail.com

cological practices (composting and intercropping) aims to optimise yields, improve soil health, and promote long-term sustainability. The creation of a Controlled Designation of Origin label serves to authenticate and elevate the olive oil quality, establishing its unique identity and distinguishing it in the market. Moreover, integrating olive oil processing, conditioning, and marketing into the Olive Growers' association ensures quality control, streamlines operations, and enhances value across the olive growers' BMC.

Keywords: Agroecological business model, food systems, olive growers, sustainability, Tunisia

Stability analysis of yield and fruit quality in inbred lines of cherry tomato

NAKARIN JEEATID, JUNSUDA MODNOK Chiang Mai University, Dept. of Plant and Soil Science, Thailand

The main aim of cherry tomato breeding is to improve stability in yield and to achieve a variety that has good consumption quality. For this purpose, a study of 12 cherry tomato genotypes (11 inbred lines and 1 commercial) was evaluated for yield and fruit quality across three environments, dry season of 2017 and 2018, at Khon Kaen (KKU1 and KKU2) and dry season 2019 at Chiang Mai (CMU). A randomised complete block design with three replications was used in each experiment. Weather data including air temperature and relative humidity and individual fruit weight, fresh yield per plant and total soluble solid data was measured. The CMU environment produced the highest average fruit weight and fruit yield while cherry tomato fruit grown under KKU1 and CMU contained TSS content higher than those grown under KKU2. From combined analysis showed significant differences among genotypes, environments, and genotype-by-environment interactions for all characteristics studied. A large proportion of variation in fruit number, fruit weight, yield, and TSS (52.6%, 74.0%, 55.4 and 58.6% respectively) was influenced by genotype. This indicates that our varieties were highly different in plant growth habits, leaf, inflorescence, and fruit sizes. Therefore, genotypes had more effect on all traits studied than other sources of variation. Genotype IL9 had medium yield and high TSS but was sensitive to environmental changes, and therefore suitable for specific location adaptation. While genotype IL3 had high yield and TSS and was more stable to environmental changes with regression coefficients on yield and TSS of b=0.74 and 0.97 respectively. Therefore, IL3 was considered suitable for various environments.

Keywords: Cherry tomato, environment, genotype, interaction, stability

Contact Address: Nakarin Jeeatid, Chiang Mai University, Dept. of Plant and Soil Science, Huay Kaew Road, Muang District, 50200 Chiang Mai, Thailand, e-mail: nakarin.j@cmu.ac.th

Optimising soil health in Africa: A holistic approach to fertiliser management with *ex situ* organic resources

Pierre Ellssel¹, Sieg Snapp², Saussure Stephanie³, Fortunate Nyakanda⁴, Frank Place⁵, Cargele Masso⁶, William Burke⁷, Helena Posthumus⁸, Bernhard Freyer⁹

¹BOKU University, Dept. of Crop Sciences, Austria

²CIMMYT, Sustainable Agrifood Systems, Mexico

³Research Institute of Organic Agriculture (FIBL), Dept. of Crop Sciences, Switzerland

⁴Zimbabwe Organic Producers and Promoters Association, Zimbabwe

⁵*International Food Policy Research Institute (IFPRI), United States*

⁶International Institute of Tropical Agriculture (IITA), Kenya

- ⁷Michigan State University, Dept. of Agricultural, Food, and Resource Economics, United States
- ⁸Wageningen University & Research, Wageningen Centre for Development Innovation, The Netherlands

⁹BOKU University, Div. of Organic Farming, Austria

Addressing soil health is being recognised as a key means to improve fertiliser efficiency, and nowhere is this more important than in Africa where fertiliser is a scarce resource, and highly expensive. Productivity and stable yields require investment in soil health integral to nutrient management. Organic inputs provide a means to recouple carbon and nutrient supply, which is essential to effective nutrient management for crop response.

Farm internal adaptations in organic matter management, including crop rotation, alley cropping, compost, animal manure and bioslurry, adjusted soil tillage, and specifically the inclusion of leguminous crops, play a crucial role to balance soil health and nutrient management.

In addition, *ex situ* organic fertilisers produced from farm external sources, like household waste, human faeces, market and agro-processing residues are valuable sources for composting and bioslurry production to further address carbon and nutrient deficiencies. Their proper use not only benefits farms but also reduces a considerable environmental burden due to their current mismanagement in many regions. Furthermore, biofertilisers (fungus-and bacteria-based) and soil amendments (like lime and biochar) can contribute to an increase of nutrient availability, functionality of soil characteristics and crop health. A strategic and considerate use of inorganic fertilisers can address specific nutrient deficiencies and provide readily available nitro-gen, promoting yield and soil health.

This study explores a holistic approach to fertiliser management, examining

Contact Address: Pierre Ellssel, BOKU University, Dept. of Crop Sciences, Gregor-Mendel-Strasse 33, 1180 Vienna, Austria, e-mail: pierre.ellssel@boku.ac.at

the effects of various input and management strategies on soil productivity. Specifically, it highlights the contribution of externally sourced organic fertilisers (ex-situ) investigated across 12 African countries through expert interviews, a review of the literature, and a comparison of the effectiveness of diverse organic matter and nutrient sources through a modelled application of nutrient and carbon balances in three smallholder farming systems (stockless, mixed, and permanent tree-based systems) with annual rainfall ranging from 800 to 1800 mm. This is a first step, with full awareness that carbon budgets are not sufficient to explain soil organic matter accrual alone. Relinking carbon inputs with nutrients is an important aspect of soil health maintenance that has been under invested in, and this study is a starting place.

Keywords: Africa, biostimulants, fertiliser efficiency, organic fertiliser, soil amendments, soil health, soil organic carbon

Co-production of Buddhist agroecological knowledge in Thailand

PATCHARIN SAE-HENG¹, ANDREA KNIERIM¹, SUKANYA SEREENONCHAI², QIRUI LI¹ ¹University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany

²Mahidol University, Fac. of Environment and Resource Studies, Thailand

Agroecological transition (AET) refers to a systematic transformation which inheres in the ecologisation of agriculture and food and is characterised by inclusion of multiple stakeholders and a political intention to transform or bring about a change. However, many agroecological experiments and studies in the socio-ecological system field fails to include the consideration of cultural landscape. Local knowledge is still seldom incorporated into research and decision-making process. Moreover, there is limited research, dedicating to investigate how the value and ethic aspect of traditional ecological knowledge (TEK) is applied in natural resource management. In Thailand, a set of alternative farming practices was developed based on the mobilised Buddhist concepts with the aims to pursue resource conservation and sustainability. To trace the historical and ideological sources of this development, the emergent agroecology in Thailand was originated from the food sovereignty concepts, the sufficiency economy philosophy (SEP) and engaged Buddhist perspectives, influenced by spiritual leaders. This research aims to understand how value and ethic aspect of Buddhism and Thai traditional ecological knowledge (TEK) are used in the current development of the agroecological transition in Thailand. This research conducts an empirical study, using the 'Sufficiency Economy Development Zones for Sustainable Development Goals (SEDZ) project in Thailand as a case study. The project was established to address the problems of natural disasters, particularly drought, flooding and sea water intrusion which affect farmers in rural areas in Thailand. The main implementation target of this project is to promote agroecological practices based on Buddhist principles, the Sufficiency Economy Philosophy (SEP) and Thai traditional ecological knowledge. This research uses actor network theory (ANT) to investigate the process of co-producing knowledge, taking place in this collaborative project. In a Buddhist country, Buddha's teachings are interpreted for modern life and provide practical and metaphorical applications for other aspects of human connectivity with nature, particularly agriculture. Despite the strong influence of Western concepts in Thais' environmental thought, there has been an increase of local environmental movements, who advocate against intensive agriculture and have inquired for a value-based principles in modern applications of traditional Thai environmental values and Buddhism.

Keywords: Actor-network theory, agroecological transition, Buddhist agriculture, coproduction, traditional ecological knowledge

Contact Address: Patcharin Sae-Heng, University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Schloss Hohenheim 1C, 70593 Stuttgart, Germany, e-mail: patcharin.saeheng@uni-hohenheim.de

Shifting spotlight from crop yield to crop diversity for climate resilient agriculture system

Chanda Kumari¹, Roopam Shukla¹, Christoph Gornott²

¹Indian Institute of Technology, Roorkee, Centre of Excellence in Disaster Mitigation and Management (CoEDMM), India

²Potsdam Institute for Climate Impact Research (PIK), Climate Resilience - Climate Impacts and Adaptation, Germany

Diversification – a key practice in agroecology – plays a crucial role in shaping resilient agricultural systems. It focuses on transitioning from monoculture practices to multiple crop systems thereby enhancing soil health and promote livelihood diversification for farmers. Compounding to the adverse impacts of climate change, the extensive use of pesticides and herbicides (usually in monocultures), lead to the deterioration in soil fertility and ultimately impacts the crop yields. Thus, to optimise the crop yield and to make crop system resilient enhancement of crop diversity is suggested. Enhanced crop diversity allows farmers to rely on multiple crops, mitigating risks associated with crop failures, reducing risks from pests, climate events, and market fluctuations and supports biodiversity conservation. This study aims to assess the crop diversity in 20 agroecological zones of India using indices like the Shannon Index, Simpson Index, and Margalef Index and to understand the spatiotemporal trend of crop diversity. The data ranges from 1997-2017 on yield and production of 56 crops grown in 711 districts of India. The goal is to identify the regions with increasing or decreasing patterns of crop diversity. Mann-Kendall (MK), modified Mann-Kendall (MMK), bootstrapped Mann-Kendall (BMK), innovative trend analysis (ITA), and detrended fluctuation analysis (DFA) tests were employed in this study to analyse the trends. The results of the study will help in identifying the leading and the lagger zones which need immediate interventions to improve crop diversity. Further, the zones are classified on the basis of low crop diversity-high yield (loss-win), high diversity-high yield (win-win), low diversity-low yield (loss-loss) and high diversity-low yield (win-loss) to unravel the trade-offs and understands pathways for creating win-win conditions across all agroecological regions.

Keywords: Agrobiodiversity, agroecological yones, India, Margalef index, Shannon index, Simpson index

Contact Address: Chanda Kumari, Indian Institute of Technology, Roorkee, Centre of Excellence in Disaster Mitigation and Management (CoEDMM), Room 110 block 2 himalaya hostel iit roorkee, 247667 Roorkee, India, e-mail: chanda_k@dm.iitr.ac.in

Transdisciplinary knowledge transfer for accelerated sustainable transformation of agri-food systems

Marcus Giese¹, Maria Oguche¹, Katrin Winkler¹, Sintayehu Yigrem Mersha², Tesfaye Abebe Amdie³

¹University of Hohenheim, Inst. of Agric. Sci. in the Tropics, Germany ²Hawassa University, School of Animal and Range Sciences, Ethiopia

³Hawassa University, School of Plant and Horticultural Sci., Ethiopia

Agricultural production and productivity in African communities are constrained by natural factors such as climate variability and change. Also limiting the agricultural sector are other factors such as policy and governance, economy and adoption of technologies. Nature-based solutions and agroecological concepts offer a holistic approach to sustainable agriculture, addressing environmental, social, and economic challenges while ensuring food security and resilience in the face of climate change. However, the implementation and acceptance of promising, sometimes paradigmchanging concepts is often a very slow process. The DAAD Agriculture Alumni Training Network with an overall theme of "Pathways for Sustainable Agro-Ecosystems Transformation in Africa" organised a travelling workshop in Ethiopia with a thematic focus on 'Nature-based Solutions and Agro-ecological Concepts. The aim was to explore and analyse current practices in the agricultural sector and what this holds for the future of sustainable agricultural transformations from the transdisciplinary perspectives of the various stakeholders. Examining the workshop activities, presentations, and field visits the adoption of these approaches was identified to be existent in the livestock, crop and socio-economics sectors such as organic farming, biogas production, and agroforestry amongst others. The multifunctional landscapes concept of trees for fertility, fodder and habitat; crops for diversification and organic matter including underutilised species; erosion control and rehabilitation of degraded landscapes; and the crop-livestock integration provides a comprehensive understanding of the socio-economic relevance and implications of these concepts in the agricultural sector. This also offers the opportunity for synergies and collaborations among various stakeholders, including the application of traditional knowledge. While these concepts have the potential to address the aforementioned challenges, promote sustainable development, and enhance livelihoods, the associated trade-offs in the scalability, the required knowledge base and transfer, implications and viability of these concepts in the context of sustainability still need to be addressed. Collaborative, transdisciplinary efforts among governments, the private sector, scientists, communities and farmers can design more effective policies and interventions that support naturebased concepts in contributing to Ethiopia's more resilient, equitable, and prosperous agricultural sector. Such transdisciplinary concepts will likely accelerate the process of transformation and thus ultimately benefit both communities and the environment.

Keywords: Nature-based solutions, systems integration, transdisciplinary approach

Contact Address: Maria Oguche, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Stuttgart, Germany, e-mail: maria.oguche@uni-hohenheim.de

Transforming sorghum farming in semi-arid Burkina Faso through agroecological intensification

Silke Stöber¹, Guillaume Ouattara², Samuel Kalaydjian³, Md Sakline Shawon⁴, Judith Henze¹

¹Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Germany

²Bureau National des Sols (BUNASOLS), Burkina Faso

³Association Koassanga, Burkina Faso

⁴Humboldt-Universität zu Berlin, Albrecht Daniel Thaer Institute, Germany

Sorghum (*Sorghum bicolor* (L.) Moench) is the most crucial staple crop for rural households in Burkina Faso. The changing climate and declining soil fertility are reducing sorghum yields. In 2021, the average yield was 900 kg ha⁻¹, and in the Plateau-Central it was only 625 kg ha⁻¹.

In 2023, an inter-farm comparison trial was set up in the Plateau-Central of Burkina Faso in cooperation with the NGO Koassanga. This trial was supported by the European Research Area Network Cofund (ERA-NET) Food Systems and Climate (FOSC) of the project Nutrigreen. It quantified the yield gains by applying the Agricultural Production and Soil Restoration Process (PPARS) method used by the NGO in more than 300 villages. Their integrated strategy includes reducing risks related to climate variability and markets, intensifying agricultural yields and restoring degraded soils. A randomised complete block design was used with four treatment plots of 10×10 metres (mother trial). The replication was done inter-farm in four villages under similar agro-climatic and soil fertility conditions. Soil samples were taken before planting and after harvest. The two-factorial trial was each combined at two levels: local sorghum seed/ Sorghum vr. Kapelga/Flagnon with manure (farmer-style) P1(control)/P2, with 2 tha⁻¹ of composted manure P3/P4, respectively.

The farmers were trained to design the research, implement the PPARS system with seven agroecological practices, maintain the plots, and evaluate the harvests by measuring seven traits (number of plants, stem size, panicle length, panicle weight, 1000 grain weight, harvest weight of stem and grains). 36 farmers established copy fields (baby trials). The statistical analysis included normal distribution check, Levene's homogeneity test, ANOVA and post-hoc tests. The results show significant differences between treatments in all traits. In two villages with higher soil fertility, P4 yields tripled or increased fivefold compared to P1 (control). In plots with lower soil fertility, the control fields P1 suffered a total crop failure, while the P4 treatment yielded 500 to 800 kg ha⁻¹. This study highlights the potential of the application of composted manure and improved seed to lift the rural population out of food insecurity in record time.

Keywords: Agroecology, Burkina Faso, ecological intensification, farmer-led research, food security, inter-farm comparison trial, sorghum

Contact Address: Silke Stöber, Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Hessische Str 1-2, 10115 Berlin, Germany, e-mail: silke.stoeber@agrar.hu-berlin.de
Soil organic carbon storage over 17 years of organic and conventional farming in central India

Namya Mathur¹, Bhupendra Singh Sisodia^{2,4}, Kamlesh Sharma^{2,4}, Georg Cadisch³, Akanksha Singh⁴, Steffen Schweizer¹

¹Technical University of Munich, Soil Science, Germany

²bioRe Association, India

³University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

⁴Research Institute of Organic Agriculture FiBL, Dept. of Intern. Coop., Switzerland

Intensified agricultural production increases the strain on soil fertility, especially in regions with high population growth such as India. Organic farming is advocated to sustain soil fertility and increase carbon storage in soils. However, there is limited understanding about the rate and factors driving soil organic carbon (SOC) storage in clay-rich soils under organic farming, specifically in a sub-tropical climate. Here, we analysed SOC storage over 17 years comparing organic and conventional agricultural systems in Central India in a long-term experiment of the Research Institute of Organic Agriculture (FiBL). We additionally evaluated to which extent particulate and mineralassociated soil organic matter (SOM) pools in the farming systems are related with the dynamics of physicochemical soil properties over time to better understand how these may hamper or enhance the build-up of SOC. Lastly, we related the change of SOC storage over time with the cotton yield as SOC can directly impact crop yield. The soil organic carbon storage was evaluated by size fractionation distinguishing particulate organic matter (OM) >20 μ m and mineral-associated OM <20 μ m. The development of soil organic carbon fractions is interrelated with physicochemical soil properties (such as clay content, pH, electrical conductivity, and exchangeable cations) as well as cotton yield. Preliminary analysis shows that it took more than 10 years to obtain a higher SOC in the organic (approx. 8 mg g^{-1}) compared to conventional farming systems (approx. 4 mg g^{-1}). We expect organic farming systems to have higher organic carbon storage in particulate OM, greater total nitrogen, and increased cation exchange capacity. In this contribution, we aim to discuss the main driving factors of soil organic carbon storage in subtropical agriculture and how it may increase soil fertility as a basis for sustainable agroecosystems.

Keywords: Organic and conventional farming, organic carbon storage, organic matter pools, subtropical Vertisols

Contact Address: Namya Mathur, Technical University of Munich, Soil Science, Kammerhof 2, 85354 Freising, Germany, e-mail: namya.mathur@tum.de

Characterisation of biochar derived from shea waste through slow pyrolysis

ANGELA LARTEY-YOUNG¹, SYLVIA AGYARKOWAA ZIGGAH² ¹University of Cape Coast, Dept. of Soil Science, Ghana ²Presbyterian Agriculture Services, Development and Social Services, Ghana

The insurgence of population growth has Ghana dealing with waste management issues. The demand for some produce coupled with production is one major cause for waste generation. These waste generated end up in built up landfills or in some instances pile up in unapproved locations creating nuisances in the communities. This is a case in Ghana. Soils in Ghana has over the years been recorded to be poor and thus, makes agriculture intensification in the country largely dependent on chemical fertilisation (inorganic) which is not easily accessible to farmers due to its high cost and limited quantity. These issues however, can be addressed through the conversion of waste into Biochar to improve soil quality and to serve as carbon sink. The objectives of this study were to: Produce biochar from SW feed stock (SWB): To evaluate some physico - chemical properties of the SWB relevant to soil health under different temperature regimes (surface function group analysis. pH. electrical conductivity, ash, bulk density and yield). Results showed that the pH of the SWB fell within the neutral range of 6.8 at 350 °C to 13 at 700 °C. These pH values obtained makes the SWB suitable for both acidic and alkaline soil remediation. The surface functional group examination was done using the Nuclear Magnetic Resonance Spectroscopy (NMR). The NMR analysis clearly displayed how the introduction of the heat on the feedstock during the pyrolysis decreased the relative proportions of the functional groups. The surface functional group was composed of oxygen at 700 °C, which is good and helps to reduce nutrient leaching by enhancing the cation and anion exchange capacities in soils. Bulk density range was within 1.26 to 1.01 g cm⁻³. The organic carbon content reached 58 % at 700 °C indicating the tendency of SWB to increases soil CEC. This study suggests the positive potentials of SWB application on soil fertility and quality enhancement.

Keywords: Biochar, shea butter, soil fertility, soil quality, waste

Contact Address: Angela Lartey-Young, University of Cape Coast, Dept. of Soil Science, Cape Coast, Ghana, e-mail: angela.arthur@ucc.edu.gh

Assessing regional performance of agroecology – comparing two contrasting case studies in Burkina Faso

Johannes Schuler¹, Hycenth Tim Ndah^{2,1}, Yasmina Tega³, Baba Ouattara³, Eveline Sawadogo-Compaore³, Hamado Sawadogo³, Souleymane Ouédraogo³

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

²University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany

³Inst. of Environment and Agricultural Research (INERA), Burkina Faso

Agroecology is suggested as a holistic sustainable solution for farmers in Burkina Faso to overcome challenges such as climate change. However, it remains unclear to what extent agroecology is yet part of regional farming systems. The purpose of this study was to assess the level of agroecology implementation in two contrasting regions. We utilised the first step of the Tool for Agroecology Performance Evaluation (TAPE), a comprehensive tool that measures the multidimensional performance of agroecological systems towards the ten elements defined by the Food and Agriculture Organisation (FAO). The study was conducted in two rural regions in Burkina Faso, one in the Northern dry zone, one in a more humid zone in the Southwest. The tool was applied in a two-day multi-stakeholder workshop (one per region) with farmers and other stakeholders. With an in-depth knowledge and understanding of the case study context, participants decided conjointly on the validity of a set of given statements describing the regional situation. The findings reveal a mixed level of performance regarding the application of the 10 agroecological elements. Farmers in the southern region state a higher diversity of their production as compared to the north (e.g. crops, trees, animals and diversity of activities, products and services). Also the application of synergies (e.g. crop-livestock integration, agroforesty), the perceived resilience of the farming systems (e.g. stability of income), the preservation of culture and food traditions and the conditions to support human and social values were perceived stronger in the southern region. Only the element "circular and solidarity economy" was seen stronger in the Northern region, while the remaining elements were reflected equally in both regions. We conclude that conditions in regions with harsh climates, limited crop options and challenges with agroforestry and crop-livestock integration may weaken resilience. However, such conditions can enforce networks among farmers that create a circular and solidarity economy. The application of the TAPE tool can serve only as a rough diagnostic instrument to assess the performance of agroecology. Therefore, farms should be individually assessed in order to understand the advantages of agroecological practices and interrelations as compared to older mainstream practices.

Keywords: Agroecology, Burkina Faso, transition

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

Unlocking the global potential competitiveness of Myanmar's rice sector: A comparative study of production costs and efficiency

Nandar Aye Chan¹, Orkhan Sariyev¹, Mohammad A. Islam², Manfred Zeller¹

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

²Bangladesh Rice Research Institute, Agricultural Economics Division, Bangladesh

Rice is crucial for the food security of over half of the world's population. However, ensuring a consistent global rice supply to meet the growing future rice demand faces significant challenges due to factors such as adverse impacts of climate change and shocks in energy and fertiliser prices. Trade restrictions pose an additional risk to rice prices, potentially affecting global food security. Myanmar plays an important role in the global rice market, representing 4.3% (2.34 million tons) of the global rice export volume in 2022. Understanding the competitiveness of Myanmar's rice industry is vital for maximising its global potential. This paper aims to analyse the cost competitiveness of rice production in Myanmar, specifically by assessing production costs, estimating cost efficiency, and investigating the potential effect of improving cost efficiency on the country's overall global competitiveness. To achieve this, we conduct a comparative analysis of production costs among major rice-producing countries and estimate the cost efficiency of rice farming in Myanmar using a stochastic frontier cost function model. Subsequently, we analyse how cost efficiency affects domestic resource costs (DRC), a key indicator of global competitiveness, by addressing the endogeneity issue that prior research has not dealt with. We consider seasonal variations across both the dry and wet seasons in Myanmar, an aspect often overlooked in previous research. Our findings reveal that Myanmar ranks as the secondcheapest rice-producing country globally. For the dry and wet seasons, the mean cost efficiencies are 89% and 86%, respectively, indicating higher efficiency during the dry season. Both dry and wet-season rice production demonstrate a comparative advantage, with DRC values of 0.31 and 0.54, respectively. The results also show that cost efficiency positively contributes to global competitiveness in both seasons, implying that the global competitiveness of Myanmar's rice sector can increase through the improvement of cost efficiency. Therefore, policy interventions aimed at developing demand-driven high-yield potential with stress-tolerant rice varieties, promoting the utilisation of quality seed, providing more extensive training on input management practices, and educational programmes for farmers are recommended to enhance cost efficiency, which can further strengthen the country's competitiveness in the global rice market.

Keywords: Competitiveness, cost efficiency, global rice market, Myanmar

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

Cost benefit analysis of agroecological transition: A case of mango value chain in Kenya

Aurillia Manjella Ndiwa, Kevin Onyango, Peter Bolo, Rosina Wanyama, Christine G. Kiria

The Alliance of Bioversity International & CIAT, Kenya

Agroecology has been highlighted as a sustainable approach that could support food system transformation in many low- and middle-income countries. Food system actors adopt agroecological (AE) principles to improve economic, environmental and social benefits within the food system. However, there is limited evidence on the cost and benefits (CBs) associated with AE transition. The goal of this study was to assess the CBs associated with AE transition in the mango value chain (VC) in Makueni County, Kenya. Mango is an important source of income and livelihood for many food system actors within the County. A co-design workshop was conducted to identify business models and innovations important for the AE transition. Two models were identified. First, the public business model which involves farmers selling mangoes to public processors through cooperatives. Innovations identified for AE transition were intercropping, activities related to reduced post-harvest losses, and the use of organic inputs. Second, the private business model which consists of individual farmers selling their mangoes to private processing companies. Innovations identified were use of organic inputs, intercropping, and expansion of business through enterprise diversification. A cost and benefit analysis (CBA) was conducted on both business models, covering farm and business levels. Net present value (NPV), internal rate of return (IRR) and Benefit-Cost Ration (BCR) were used to assess the economic CBs, while content analysis was used to assess the social and environmental CBs in the two business models. Preliminary findings show that benefits associated with AE transition are significantly higher than the costs at both farm and business levels. At farm level the NPV ranged between US\$300 and US\$400, a positive BCR (>3) with a payback period of two years while the IRR ranged between 100 % and 250 %. This means the AE transition at the farm level is profitable. At business level the NPV were above US\$19,095, with a positive IRR of less than 115%, a BCR of >1 and a payback period of three years, implying that the business side will make an economic profit with AE transition. The manuscript provides additional findings on the social and environmental benefits, and overall study recommendations.

Keywords: Africa, agroecology, cost benefit analysis, developing countries

Contact Address: Aurillia Manjella Ndiwa, International Institute of Tropical Agriculture (IITA), East Africa Hub, Nairobi, Kenya, e-mail: a.ndiwa@cgiar.org

Agroecological transitions in value chain: A multiple case analysis

ANDRÉS CHARRY, ALEJANDRA VARGAS, MANUEL NARJES, CAROLINA GONZALEZ The Alliance of Bioversity International & CIAT, Colombia

Agroecology is increasingly recognised as a promising solution to address the multiple challenges confronting our current agricultural and food systems. While evidence underscores its potential to enhance the health and sustainability of food systems, there remains a critical knowledge gap regarding the successful scaling of agroecological practices particularly in the Global South. Within the CGIAR Initiative on Agroecology, we are aiming at understanding the mechanisms conducive to the adoption and expansion of agroecological principles across diverse countries, each marked by unique agroecological, cultural, and sociopolitical contexts. Termed Agroecological Living Landscapes, these efforts encompass the development of business models and commercial enterprises as essential components. To identify viable business models aligned with agroecological principles, we conducted rapid value chain assessments with an agroecological lens. Evaluating current agroecological practices vis-a-vis the 13 Agroecological Principles delineated by the HLPE, we assessed ten value chains across six countries (Burkina Faso, India, Kenya, Peru, Tunisia, and Zimbabwe). Our analysis allowed to better understand the value chain structures and flows, while highlighting relevant opportunities, challenges, and enabling factors for a broader adoption of agroecological principles in farms and commercial enterprises. Across the ten value chains, the principles integrated focused mostly on improving resource efficiency and strengthening resilience, with a notable dearth in activities promoting social equity-a less tangible, yet key aspect prioritised disparately among stakeholders. Major barriers stem from information and input scarcity and lack of consistency, absence of standardised products and processes, labour and land constraints, infrastructure inadequacies, and limited access to incentives and support services. These challenges, though pervasive in conventional food systems, are even more hindering for stakeholders interested in integrating agroecological practices. We anticipate that our findings will facilitate the replication of similar interventions in diverse regions, while also documenting diverse pathways to inform, caution, or inspire other stakeholders in advancing agroecology across varied landscapes.

Keywords: Agroecological living landscapes, agroecological transitions, case study, upscaling innovations, value chains

Contact Address: Andrés Charry, The Alliance of Bioversity International & CIAT, Km 17 recta Cali - Palmira, Cali, Colombia, e-mail: a.charry@cgiar.org

Analyse land use land cover (LULC) dynamics in a cocoa landscape context (Côte d'Ivoire)

Bonna Antoinette Tokou¹, Kueshi Semanou Dahan¹, Constant Yves Adou Yao², Stefan Sieber¹, Katharina Löhr¹

¹Leibniz-Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

²Félix Houphouët-Boigny University, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire

Over the past three decades, cocoa production and deforested areas have increased in the country due to the intensification and expansion of cocoa production. Cocoa production systems face numerous challenges, including environmental degradation, climate change impact, and socioeconomic pressures. Understanding the dynamics of these systems is crucial for developing sustainable and resilient cocoa production practices. This study examines how various drivers: land tenure, demographics, deforestation rates, diversification strategies, and adoption of agroforestry systems influence LULC patterns over time. This study identifies the dominant land use types, examines transformative trends of change land use transitions for the period 2002–2023, and as well as the intensity analysis of land use transitions for the same period. Advanced remote sensing approaches such as Random Forest classification are used to assess land use changes across the cocoa landscape. By analysing the relationships between these factors and LULC changes over time, the Random Forest model identifies key drivers of landscape transformation within cocoa production areas. Indeed, Landsat satellite data were used, along with data from the description, location, and photography of the sites visited. In addition, data on farmers' demographic characteristics, land-use practices, and land-change factors were collected using interview methods. Statistical models to identify relationships between factors and land use dynamics are used. This study contributes to comprehensible interactions that shape cocoa landscapes. It helps to design policies that promote sustainable land management practices and highlights as well the indicators that can alert the various stakeholders to the future of the cocoa sector, especially governments, and the chocolate industry.

Keywords: Cocoa production, drivers, dynamic, land use land cover

Contact Address: Bonna Antoinette Tokou, Leibniz-Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder straβe 86, 15374 Müncheberg, Germany, e-mail: tokou.ant@gmail.com

Resource-use efficiency of rice production in the state of Odisha, India

RAMMAH ZWAN¹, MIROSLAVA BAVOROVÁ¹, PRIYA BRATA BHOI², KINDAH IBRAHIM¹ ¹Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Czech Republic

²Punjab Agricultural University, Dept of Economics and Sociology, India

In Odisha, food and nutrition security should be augmented, keeping population growth and future requirements in mind. While doing so, the productivity of rice should be raised. In order to raise the productivity of rice in the state of Odisha, the resources should be optimally utilised to get the maximum product out of the minimum possible input. This study was conducted in Odisha during 2016–17. Data about rice production, productivity, input use, costs and profitability were obtained from various issues of Odisha Statistical Abstract, the Department of Economics and Statistics, and the Ministry of Agriculture. The analysis examined rice resource productivity and profitability using two indicators MVP (Marginal Value Product) and MFC (Marginal Factor Cost) ratio. Furthermore, the technical efficiency of paddy production was estimated through the Stochastic Frontier Production (SFP) function and its estimated parameters. The Cobb-Douglas production function's maximum likelihood estimate is reported. The results of the analysis of MVP and MFC show that in all inputs, the value was less than one, indicating the overuse of the resources. The variance sigma square for the SFP model was found statistically significant, indicating the models are stochastic rather than deterministic. The estimated variance parameters sigma square U and sigma square V significantly differed from zero, indicating that the inefficiency in paddy production was not due to chance alone but to individual inefficiency. Further, the value of Lambda, depicting the degree of asymmetry in the distribution composite error term, was significant, suggesting the existence of a high degree of technical inefficiency and dominance of a onesided error component. The value of gamma, which has a 46.6 % variation in paddy productivity, could be attributed to technical efficiency. Based on the results, the government should create easy access to supply farm inputs at a subsidy rate to the farmers to reduce the cost of rice cultivation and improve the profit margin of farmers. Steps must be taken to strengthen the extension services, access to machinery and improving technical knowledge.

Keywords: Cobb-Douglas, India, resource use efficiency, rice production

Contact Address: Rammah Zwan, Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Prague, Czechia, 16500 Praha - suchdol, Czech Republic, e-mail: zwan@ftz.czu.cz

Sustainability of sesame farm households supported by Orge NGO in the Savanes region of Togo

Міке́міла Ріlo¹, Anara Kpassiro Agolo¹, Koudima Bokoumbo² ¹University of Kara, Lab. of Economics and Management Sciences, Togo ²Ministry of Agriculture, Research and Vulgarisation, Togo

A sustainable farm management fulfils the three dimensions of sustainability, namely the environmental, economic, and social dimension. However, despite the availability of social and technological innovations, sustainability is yet to be reached. Under the hypothesis that the support of agricultural technicians and advisors could help meet this challenge, the Orge NGO is investing in supporting sesame production farm households in Togo. The objective of this research is to assess the sustainability of production systems in the sesame sector supported by the Orge NGO in the Savanes region of Togo. The data used for the analyses comes from a field survey of 111 sesame producers supported by the Orge NGO in five districts in the region. The analysis is based on the Deep Participatory Indicator-Based (DPIB) approach, which is based on the sustainable development goals paradigm. The results of the analysis indicate the environmental (78.63), economic (40.05) and social (45.50) sustainability scores, based on a scale of 100. This means that the considered sesame production systems are sustainable from an environmental point of view but not sustainable from an economic and social point of view. Thus, the key message drawn from the findings is that the current Orge accompaniments practices are insufficient to guarantee sesame farm households' sustainability as promoted by the United Nations. The social unsustainability of the farms is explained by the poor performance recorded in terms of food security, quality of life and social involvement. As for economic unsustainability, it is the result of low availability of capital, low returns recorded and low technical efficiency. Thus, for sesame farms to move towards sustainable agricultural systems under the paradigm of sustainable development goals, training producers to use more profitable environmentalfriendly practices and implementing strategies allowing better access to capital are important pillars.

Keywords: Deep participatory indicator-based approach, Savanes region of Togo, sustainability

Contact Address: Mikémina Pilo, University of Kara, Lab. of Economics and Management Sciences, Kara, Togo, e-mail: pilomikemina15@gmail.com

Energy efficiency on smallholder farms in southern Brazil: An agroecological approach

DENIS SOLDERA, STEPHANIE DOMPTAIL

Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Germany

Agricultural practices often depend on fossil energy, resulting in adverse socioeconomic and environmental impacts. Agroecology offers potential energyefficient farming practices that maximise output whilst minimising external energy inputs. In Brazil, agroecological farms aim to reduce external energy consumption through internal resource cycling, particularly biomass reuse. However, the impact of these recycling practices on energy efficiency remains unclear, despite extensive Brazilian literature on agroecology. This study addresses this knowledge gap by applying the Agroecological Energy Analysis (AEA) method to a case study of 27 farms in Southern Brazil. The AEA is an energy-flow analysis and multi-EROI (Energy Return on Investment) approach grounded in the social metabolism framework that accounts for biomass reuse in energy balances to measure the impact of such practices on energy efficiency. The results indicate that farms with higher levels of biomass reuse demonstrate reduced reliance on external inputs but do not consistently achieve higher energy efficiency. Although biomass reuse aligns with the principles of agroecology by reducing dependence on external inputs in some cases, it does not uniformly lead to energy savings across the farms studied. The reliance on external inputs, particularly organic fertilisers, is a noticeable pattern in the case study. This indicates that the substitution effect may be minimal or marginal across the analysed farms. This study highlights the importance of considering other factors, such as labour intensity when evaluating energy-saving practices in agroecological farming. It observes the complexity of achieving energy efficiency through biomass reuse and reinforces the need for a broader evaluation framework that encompasses various farm-specific variables.

Keywords: Agroecology, energy-flow analysis, multi-EROI, social metabolism

Contact Address: Denis Soldera, Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Senckenbergstraße 3 Zeughaus, 35390 Giessen, Germany, e-mail: denis.soldera@agrar.uni-giessen.de

Economic benefits through agroecology: ProSoil's scientific evidence for farmers and society

Matti Cartsburg, Juliane Kaufmann, Alica Nagel HFFA Research, Germany

The potential of agroecological practices to improve soil quality and sustainability in agricultural systems is increasingly recognised. Evidence of economic efficiency, on the other hand, is still rare. This brief assesses the economic impact of agroecological practices by reviewing scientific evidence from Benin, Burkina Faso, Ethiopia, India, Kenya, Madagascar, and Tunisia in the context of the Programme "Soil Protection and Rehabilitation for Food Security (ProSoil)" implemented by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, commissioned by the German Federal Ministry of Economic Cooperation and Development (BMZ) and co-funded by the European Union (EU) and the Bill & Melinda Gates Foundation. The key questions were whether agroecological practices are economically viable for the individual farmers, and whether they contribute to broader societal benefits. The review shows that the implemented agroecological interventions significantly benefit farmers economically, with positive returns observed in all surveyed regions and across almost all investigated case studies. Soil and water conservation measures such as the creation of vegetation strips or dams not only enabled the expansion of arable land in the intervention areas, but in some cases also led to vield increases, which resulted in higher incomes for farmers. Also integrated soil fertility management, in which liquid manure or organic fertilisers were used, led to major financial benefits in the studies examined. Agroforestry and intercropping as part of sustainable land management methods generally resulted in increased crop yields and greater net benefits in the majority of instances. The implemented practices also showed positive effects on a societal level and could be associated with reduced public health costs, carbon sequestration, or climate change mitigation. The impact of agroecological practices varies depending on local conditions and sometimes requires higher labour input compared to conventional practices. For this reason, tailoring implemented practices to specific regional conditions to maximise economic and societal benefits is crucial. To enhance these benefits, it is further important to provide policy support and capacity building for the dissemination of practices that can improve soil remediation. Agroecology provides a long-term solution for productive and sustainable agriculture if prioritised and equipped with the necessary resources.

Keywords: Agroforestry, environmental resilience, food security, intercropping

Contact Address: Juliane Kaufmann, HFFA Research, Bülowstraße 66, 10783 Berlin, Germany, e-mail: juliane.kaufmann@hffa-research.com

The digital information system quarantine pests (DISQS): A central solution for surveys in Germany

Fabio Dorn¹, Silke Steinmöller¹, Bruno Kessler², Manfred Röhrig²

¹Julius Kühn Institute (JKI) – Federal Research Centre for Cultivated Plants, Inst. for National and International Plant Health, Germany ²Informationssystem Integrierte Pflanzenproduktion (ISIP) e.V., Germany

The surveys on the presence of Union quarantine pests are part of the early warning system of the European Union. Early detection of a pest introduction is the basis for successful eradication with reasonable effort. This can prevent establishment and further spread of the pests. The implementing regulation 2019/2072 lists 395 Union quarantine pests, which have to be surveyed through multi-year programmes in the member states since 2020. These Union quarantine pests are species of bacteria, fungi, oomycetes, viruses, viroids, phytoplasmas, insects, mites, nematodes, mollusks and parasitic plants. The precise planning and digitalized documentation of the surveys is of great importance considering the large number of pests, which have to be survey by the plant protection services. Nevertheless, little information is available on many pests. The European Food Safety Authority (EFSA) is gradually developing so-called "Pest Survey Cards" which contain all scientific information that may be relevant for survey planning. These cards cannot be used directly for Germany, as they have to take into account the entire territory of the EU. Currently, Germany is experiencing at the federal and state level an enormous amount of redundant work on literature research as preperation of the surveys. In addition, the documentation and evaluation is mainly manual, as no central system is available to which all participants have access. The project aims to create a digital and centralised solution for surveys of Union quarantine pests in Germany. On the one hand, the storage and processing of data for planning and, on the other hand, the flexible evaluation and presentation of the surveys will be accessible. This should enable the direct information retrieval for the planning. In the form of a database, information on the pests including their biology, countries of origin, routes of spread, diagnosis, factors relevant to the survey, etc. will be collected. In addition, the information in this database will be linked to the tool for collecting the monitoring data. This tool will greatly simplify the work of the state and federal agencies in collecting, evaluating and disseminating the data for a wide variety of purposes. This will also enable the development of clear evaluation modules of the survey data for Germany for the first time. The technical implementation is carried out by the project partner "Informationssystem Integrierte Pflanzenproduktion (ISIP) e.V. ", the joint advisory portal of the chambers of agriculture and the federal states.

Contact Address: Fabio Dorn, Julius Kühn Institute (JKI) – Federal Research Centre for Cultivated Plants, Inst. for National and International Plant Health, Braunschweig, Germany, e-mail: fabio.dorn@julius-kuehn.de

Insights into participatory guarantee systems (PGS) in Latin America: A Paraguayan case study

NIKOLAUS HRUSCHKA, SONJA KAUFMANN, CHRISTIAN R. VOGL BOKU University, Dept. of Sustainable Agricultural Systems, Austria

In the global south, Participatory Guarantee Systems (PGS) have gained increasing importance as a mechanism to provide organic quality assurance for smallholder farmers producing for the domestic markets. PGS are local conformity assessment systems that guarantee organic integrity through participation and ownership of the stakeholders and thus offer a localised alternative to third-party organic certification systems and conventional agrifood value chains. We used semi-structured interviews (n=26), farmer surveys (n=26) and participant observations (n=3) to firstly, understand the structure of the Paraguayan PGS initiative PyOrgánico, secondly, o explore what kind of participation takes place, how, for what and by whom, thirdly, to uncover how the organic PGS control system is organised. Furthermore, we conducted a Social Network Analysis (SNA) amongst PyOrgánico stakeholders to explore how knowledge exchange regarding organic certification and organic production occurs. Our results indicate that, in contrast to the proclaimed characteristics of PGS, PyOrgánico's organisation is spearheaded by an NGO responsible for the management and the implementation of the control system of the PGS. Opposing the key characteristic of horizontality argued amongst PGS initiatives stakeholders, PyOrgánico farmers are partitioned within subgroups of the PGS and have little participation possibilities either within the initiative or in the PGS control system. Farmers' incentives in participating in the PGS was primarily linked to 'learning', 'exchange and sharing' and 'reaching a common goal'. Yet, results from the SNA show how only few actors, mostly members of the NGO distribute information to PGS farmers. Knowledge exchange regarding organic production and organic certification amongst PGS farmers was not observed across the PGS subgroups, and could only barely be observed amongst farmers within each subgroup. With the rising interest in organic agriculture by farmers and consumers in the global south, this research provides insight into characteristics of mechanisms within a PGS, and uncovers challenges of alternative food networks attempting to transform domestic agri-food value chains in Paraguay.

Keywords: Alternative food networks, farmer organisations, Latin America

Contact Address: Nikolaus Hruschka, BOKU University, Dept. of Sustainable Agricultural Systems, Gregor-Mendel-Strasse 33 03/17, 1180 Vienna, Austria, e-mail: hruschka@boku.ac.at

Krishi Kund for agroecological transition of degraded lands: Microsite for improved production and ecosystem services

SUDHARSAN MALAIAPPAN, GOPAL KUMAR, ALOK SIKKA International Water Management Institute (IWMI), India

Decades of rampant land degradation have rendered many areas unsuitable for cultivation. In Madhya Pradesh, India, land degradation along with difficult terrain, and poor soil conditions make significant portions of land unfit for cultivation leading to the migration of tribal communities. These degraded or sporadically cultivated lands are caught in a vicious cycle leading to further degradation. A cost-effective agroecological approach to transform degraded lands into productive assets using natural amendments is crucial for improving agricultural diversity, soil health, and overall ecosystem services. It also helps alleviate the pressure of intensive farming on other lands. Moreover, this practice holds promise for reversing migration among tribal communities. The CGIAR's Agroecology Initiative, in collaboration with local tribal farmers and stakeholders, has co-designed an innovative practice locally popularized as Krishi Kund (micro-site improvement with agriculture pits). This practice focuses on improving micro-sites rather than entire parcels of land using organic amendments. In this method, small cylindrical pits (did: 60 cm, depth 60 cm) are excavated at 1.2 m intervals, filled with locally available organic materials such as cow dung compost, vermicompost, plant biomass, and organic inoculants, and then covered with sieved soil. This approach improves approximately 20% (6450 pits per hectare) of the land area, resulting in a similar yield of fully restored land. Circular depressions around each pit serve as micro catchments, conserving rainwater onsite. This technique effectively enhances soil physical condition, fertility, water retention, thermal buffering leading to successful crop establishment and production. Drought tolerant crops viz pigeon pea, caster for the poor water availability sites and other cash crops including vegetables at sites of water availability are being grown. A two-year recovery period was estimated for the cost incurred on land restoration. Krishi Kund offers a resource-efficient alternative for restoring degraded lands by concentrating organic materials within specific areas and minimising soil loss. This method aligns with the goal of achieving Land Degradation Neutrality (LDN) and can significantly contribute to fulfiling Sustainable Development Goal (SDG) 15.3, which aims to end desertification and restore degraded land.

Keywords: Land restoration, soil health, water conservation

Contact Address: Sudharsan Malaiappan, International Water Management Institute (IWMI), Delhi, India, e-mail: s.maliappan@cgiar.org

Agroecological impacts of community-based land rehabilitation and soil fertility enhancement in Madhya Pradesh

Shweta Gupta, Muzna Alvi, Sonali Singh

International Food Policy Research Institute (IFPRI), Natural Resources and Resilience, India

Land degradation is a widely recognised global problem posing significant environmental, social, and economic challenges. Across the world, unsustainable land use practices, deforestation, urbanisation, and climate change have contributed to soil erosion, desertification, and loss of biodiversity. In India alone, about 30% of the land has been degraded with more than 70% of it coming from water and wind induced soil erosion.

Sub-optimal land utilisation reduces farm and livestock productivity thereby having direct implications for food security. In Madhya Pradesh, India with nearly 30 % area under forests, agricultural intensification has happened at the cost of commons such as forests, woodlands, and shrub-lands. Yield gains are lower due to poor resource flows from commons that fail to reach small and marginal farmers who lack resources for intensification. The adverse impacts of land degradation are felt most acutely by poor tribal communities who are dependent on commons for fodder, fuel wood, manure, and forest produce, all of which plays a crucial role in regulating nutrient replenishment in soils. The challenges posed by land degradation need localised solutions, and the involvement of local communities through participatory approaches offers a solution through improved social learning, building social capital, and facilitating community-based resource management.

The Foundation for Ecological Security has undertaken community-led land restoration and soil conservation efforts for improving land productivity, rural incomes, and ecosystem services of restored commons in several districts in Madhya Pradesh. By using a multidimensional lens of agroecology, we study the impact of communitybased land restoration interventions by FES on environmental, social, and economic outcomes such as biodiversity, agriculture yields, women's empowerment, and household nutrition, resilience, and economic well-being. We use an intra-household survey of 1100 households from more than 70 treatment and control villages, to conduct a rigorous impact evaluation of the interventions, allowing us to study whether and how participatory approaches to land rehabilitation and agroecological approaches can lead to sustainable land use, productive agriculture, and inclusive rural development.

Keywords: Agroecology, India, land rehabilitation

Contact Address: Shweta Gupta, International Food Policy Research Instotute (IFPRI), Natural Resources and Resilience Unit, 110012 New Delhi, India, e-mail: shweta.gupta@cgiar.org

Agroecology homestead models: Enhancing nutrition, soil health, and income for tribal farmers

Gopal Kumar¹, Sudharsan Malaiappan¹, Alok Sikka¹, Dikhyani Konwar², Saurabh Singh²

¹International Water Management Institute (IWMI), India ²Professional Assistance for Development Action (PRADAN), India

Tribal communities in Madhya Pradesh, India are characterised by limited interaction with outside world and minimal exposure to developmental initiatives, heavily rely on self-production and the collection of Non-Timber Forest Products (NTFP) for sustenance. However, this reliance often leads to imbalanced nutrition and irregular income, exacerbated by monoculture farming practices and diminishing forest resources. Coupled with widespread migration, gender inequality, and social alienation, these challenges perpetuate a cycle of poverty and malnutrition within these communities.

To address these issues, an Agroecological Homestead Model (AHM) has been developed and promoted for adoption. Unlike regions with limited land holdings, tribal farmers in this region possess sizable but degraded land. The AHM utilises homesteads, employing water harvesting and storage systems for irrigation, multi-layer cultivation, crop rotation, horticulture plants, applying natural amendments, composting, backyard poultry and goat rearing, using local seed varieties, and nutrient rich fodder for livestock. Community engagement is facilitated through resource aggregation for bio-input production, planting materials and collective marketing efforts.

Implemented on less than 0.1 hectares, the AHM, predominantly managed by women, accommodates 10 to 16 types of vegetable/crops annually. Initial support and capacity building, particularly through women led self-help groups, are crucial for adoption. Despite initial challenges such as investment requirements and knowledge gaps, the establishment of community nurseries, training on natural amendment preparation, and dissemination of knowledge on farm management were found instrumental in scaling the model. The AHM has resulted in significant improvements, including a 100% increase in dietary diversity, over 70% rise in green vegetable consumption, increase in protein intake. Soil health indicators, including organic carbon levels and water retention capacity, have shown promising improvements, validated through citizen science approach.

Multistakeholder engagement, involving government departments, research institutions, and women's groups, is essential for the model's success. Efforts are underway to explore local business opportunities linked to the AHM, leveraging existing government programs, and advocating for policy changes at the national level to address malnutrition among marginalised farmers women and children across the country.

Keywords: Agroecology, animal health, natural farming, rural livelihoods, soil health, sustainable diets

Contact Address: Gopal Kumar, International Water Management Institute (IWMI), Sustainable Water infrastructure & Ecosystems (SWIE), New Delhi, India, e-mail: g.kumar@cgiar.org

Supporting locally driven agroecological transformation through agroecological living landscapes (ALLs): A practical toolkit for implementation

Rachel Voss¹, Sarah Freed², Anne Rietveld², Thomas Falk³, Bernard Triomphe⁴, Nadia Bergamini⁵, Lisa Fuchs⁶, Chris Dickens⁷, Marcela Quintero⁸

¹*The Alliance of Bioversity International & CIAT, Germany*

²The Alliance of Bioversity International & CIAT, Kenya

³International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Germany

⁴*French Agricultural Research Centre for International Development (CIRAD), Mexico* ⁵*The Alliance of Bioversity International & CIAT, Italy*

⁶The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya

⁷International Water Management Institute (IWMI), Sri Lanka 8The Alliance of Biomenity Internetional Sci CIAT, Colombia

⁸*The Alliance of Bioversity International & CIAT, Colombia*

The identification, development, and scaling of agroecological solutions (technological and institutional) should be grounded in local needs, priorities, and constraints; informed by a comprehensive understanding of the agri-food system context; and guided by local stakeholders' shared vision. A core challenge for agroecology researchers and implementing partners therefore involves how to effectively support and enable such locally led agroecological transformation. In pursuit of this, the CGIAR Transformational Agroecology Initiative developed the concept of Agroecological Living Landscapes (ALLs), which serve as multi-stakeholder structures for action research and co-design of solutions. In this digital toolkit, we explain the principles behind and provide guidance around the set-up of ALLs, which aim to organise local actors, identify needs, develop visions, and collaboratively craft and implement localised solutions that embrace agroecological principles. Through several modules, the kit provides practical guidance for researchers and implementing partners around principles of engagement, methods for assessing actor agency and behaviour change pathways, vision-to-action exercises, stakeholder and policy mapping, fair and inclusive business plan development, and methods for co-designing innovative agroecological practices and technologies. We draw on past ALL experiences in South America, Asia, and Africa to illustrate lessons learned, with attention to challenges around governance, gender sensitivity and social inclusion, power dynamics, and other topics. We also reflect and build on key action research methodologies. Meth-

Contact Address: Rachel Voss, The Alliance of Bioversity International & CIAT, Mittenheimer Straße 19, 85764 Oberschleißheim, Germany, e-mail: rcvoss@gmail.com

ods documentation are supported with video testimony from ALL organisers and participants in locations around the world. With this toolkit, we aim to enable wider application of the ALL approach to supporting agroecological transformation led by local stakeholders and informed by scientific evidence.

Keywords: Action research, agroecology, co-design, knowledge co-production, living labs, toolkit

Consumer valuation of organic horticultural products in Lama community of Togo

Mikémina Pilo¹, Mèba Grasse Akpe², Essowè Tantiana Abalo³

¹University of Kara, Lab. of Economics and Management Sciences, Togo

²University of Kara, Agricultural and Environnement Economics, Togo

³University of Kara, Agroecology, Togo

Although organic farming is increasingly perceived as a viable alternative to conventional agriculture in the face of deteriorating environmental ecosystems, little is known about consumers' preferences for organic products in Sub-Saharan Africa particularly in Togo. This paper bridges this gap in research and investigates the extent to which consumer values organic food, specifically organic fruits and vegetables, in Lama Community in Togo. Thus, the objective of the paper is to analyse the premium for organic horticultural products in the Lama community. To do this, student difference test is used to estimate the value of the premium, bivariate Probit to analyse consumer's attitude to organic horticultural products, Ordinary Least Squares (OLS) to analyse factors that explain the premium for organic horticultural products. The analyses are based on ground data collected on 100 households in the study area. The results show that the average premium for organic fruits is 1694 F CFA (2.58 €) in periods of abundance and 3258 F CFA in periods of shortage per week while that of vegetables is 2006 F CFA (3.05 €) in periods of abundance and 3032 FCFA (4.57 €) in periods of shortage. Socio-demographic factors of the household such as size, dependency ratio, age, sex, level of education and sector of activity of the head of the household explain the decision for a household to use or not organic horticultural products. All of these results contribute to laying the foundations to promote sustainable farming practices that make use of local solutions to address global environmental challenges.

Keywords: Lama Community of Togo, organic horticultural product, premium, Probit model

Contact Address: Mèba Grasse Akpe, University of Kara, Agricultural and Environnement Economics, Togo à Kara, Togo, e-mail: akpegrace646@gmail.com

Integrating an agro-system model and remote sensing information to simulate maize and potato yields in smallholder intercropping systems on the Jos plateau, Nigeria

Esther S. Ibrahim¹, Claas Nendel¹, Jeb David Nyamo², Patrick Hostert³, Ehsan Eyshi Rezaei¹

¹Leibniz-Centre for Agric. Landscape Res. (ZALF), Data, models and simulations, Germany

²National Centre for Remote Sensing, Nigeria

³Humboldt-Universität zu Berlin, Geography Department, Germany

Smallholder agriculture is responsible for more than half of the global food yield, predominantly thrives in low- to middle-income regions of Africa, Asia, and Latin America. However, owing to the dynamic nature and diversity inherent in smallholder agriculture, accurate estimates of their production pose a formidable challenge. The use of simulation models for crop growth and yield prediction in smallholder systems is often hampered by the lack of experimental data for calibration, the capability to represent mixed cropping systems and of data for large-area assessments. We integrated remote sensing data from the Sentinel 2 mission to generate leaf area time series for model calibration. Then, we simulated yields across sole- and intercropped fields using the MONICA agroecosystem model. The results of the spatial simulations revealed the impacts of annual weather conditions and their interaction with local conditions on annual attainable yields. Potato yields between 4,200 – 7500 kg ha⁻¹ were simulated as attainable across different spatio-temporal windows and for different sowing dates. In the same manner, attainable grain maize yields were simulated in a range between 2,000 - 4,500 kg ha⁻¹. Our results further revealed higher yields for potato under mid and late sowing options. The current practice on the Jos plateau is, however, early sowing to avoid the severe impacts of diseases, and potatoes are harvested at the onset of diseases to avoid tuber decay. We therefore suggest the establishment of early warning systems to inform farmers about the best windows for sowing. The integration with remotely sensed crop type information provides a comprehensive spatial yield estimate for the Jos Plateau, revealing supplementary yields of 11% to 89 % ha⁻¹ where intercropping is practised, depending on the soil, climate, site, and management conditions of the intercropped field. Interestingly, results also implies that higher individual maize and potato yields are achieved within the intercropped fields. The overall potential mean annual maize and potato yields on the Jos Plateau is estimated to be 989,321 and 327,317 tons, respectively. Our results presents the first comprehensive yield estimated for Nigeria. Through this integrated approach, valuable insights was provided into optimising yield monitoring and food planning in SSA.

Keywords: Climate change, intercropping, mono cropping, sub-Sahara Africa

Contact Address: Esther S. Ibrahim, Leibniz-Centre for Agric. Landscape Res. (ZALF), Data, models and simulations, Eberswalder Straße 84, 10099 Müncheberg, Germany, e-mail: esther_shupel.ibrahim@zalf.de

Integrating science-based evidence for the formulation of policies to scale up the use of bio-inputs in tropical agricultural systems

Karen Montiel Lopez, Harold Gamboa

Inter-American Institute for Cooperation on Agriculture (IICA), Costa Rica

Tropical agricultural systems are generally characterised by low productivity compared to those of temperate regions and there are considerable scientific evidence as to how the use of bio-inputs (bio-fertilisers and biopesticides) reduce productivity gaps of tropical systems while responding to food security and nutrition, reduce GHG emissions, and conservation of ecosystem services. However, while there is evidence of the positive impacts of the use of bio-inputs on food systems, at the regional level, there are many barriers for scaling up the commercial use including: the challenge of transforming the agricultural technological-productive matrix to reduce the use of agrochemicals, comply with market regulations and promote environmentally friendly technologies.

Latin American and the Caribbean (LAC) countries are endowed with such a wealth of natural resources that the region is positioned as a potential world breadbasket. One of the essential resources for sustaining agricultural production is soil, which has physical, chemical and biological characteristics that are the basis for agricultural production and for providing the ecosystem services necessary to sustain life on the planet. In the tropics, soils are affected by high or very high severity of degradation (about 48 % in the Caribbean, 50 % in Mesoamerica). Management and quality of inputs added to the soil are key for soil health and regenerative agriculture.

Bio-inputs are a nature-based solution containing live microorganisms such as beneficial bacteria and fungi that improve soil health and promote biodiversity. While the region presents regulatory gaps for accelerate the adoption of bio-inputs and maximise their positive impact, on-farm production is a phenomenon that is positioning itself more strongly in the region. An innovative example is Argentina, which has created the category of biopreparations to address legislative limitations and facilitate the official registration of biological products of family farming. Governments, public and private sectors in the region are recommended to work on and strengthen regional cooperation in nomenclature, registration requirements, biosecurity standards and quality assurance.

This poster presents information on IICA's work using scientific evidence to promote policies on the use of bio-inputs in tropical systems.

Keywords: Bio-inputs, LAC, policies, science, soil health, tropical agriculture

Contact Address: Karen Montiel Lopez, Inter-American Institute for Cooperation on Agriculture, Direction of Technical Cooperation, San José, Costa Rica, e-mail: karen.montiel@iica.int

Can agroecology provide opportunities for rural youth to manage natural resources sustainably at the landscape level?

Zied Idoudi¹, Aymen Frija¹, Veronique Alary², Balkiss Bessouda³, Ghada Kortass³, Hazem Cherni³, Yassin Fadhly³, Ons Tebourbi¹, Edouard Jean³, Meghajit Shijagurumayum⁴, Nadia Guettou Djurfeldt⁵, Anne Rietveld⁵

 ¹International Center for Agricultural Research in the Dry Areas (ICARDA), Tunisia
²SELMET, CIRAD, INRAE, Institut Agro, Université Montpellier, France
³Association les Amis de CAPTE - Collectif d'Acteurs pour la Plantation et la Transition Environnementale, Tunisia
⁴The Alliance of Bioversity International & CIAT, India
⁵The Alliance of Bioversity International & CIAT, Kenya

Sustainable management of natural resources is essential for securing the future of food systems, particularly in marginal rural areas that are heavily dependent on agriculture. In Tunisia, as in many other countries, the aging of the farming population, coupled with the shift of younger generations to nonagricultural activities and outmigration, poses a significant challenge to the sustainable management of natural resources in rural areas. This trend not only hinders innovation in agricultural systems, but also threatens reproduction of knowledge and traditional practices essential for natural resource management and destabilises traditional and resilient rural livelihood patterns. Addressing this issue is critical to ensuring the long-term sustainability of agri-food systems and the livelihoods of rural societies. This requires holistic and inclusive approaches that could engage and empower youth in sustainable agricultural innovation and resource management. In other words, young people need innovative engagement approaches to help them become effective actors in building resilience to emerging challenges in rural areas and building their own viable, prosperous, and resilient livelihoods.

The study explores the nexus of youth in rural Tunisia, the role they envision for themselves in natural resource management and in building agricultural livelihoods in the Kef-Siliana transect of northwestern Tunisia. A study conducted within the framework of the CGIAR Initiative on Agroecology and carried out in semi-arid mixed landscape of cereals, trees and small ruminants has helped to identify pathways for youth engagement in this landscape from the perspective of agro-ecological transition. The paper specifically examines the barriers and opportunities perceived by young men and women within the landscape and provides actionable recommendations for alternative youth engagement pathways. A mixed-methods approach is used, consisting of semi-structured interviews, key informant in-

Contact Address: Zied Idoudi, International Center for Agricultural Research in the Dry Areas (ICARDA), Tunis, Tunisia, e-mail: z.idoudi@cgiar.org

terviews and a photovoice methodology, complemented by youth and gender differentiated analysis of implicit and explicit statements. Preliminary results show that the photovoice and storytelling methodology is very useful to depict the challenges and difficulties youth face for increased engagement in agriculture and agroecological transitions. Results also show that youth are mostly constrained by assets that can enable them to engage in sustainable entrepreneurial activities within their food system environment on the landscape.

Keywords: Agroecology, food systems, natural resources, Tunisia, youth

Motivational drivers for choices of agricultural production systems: A comparative study of farmers in Tanzania and Niger

Tanay Joshi¹, Alexander Heer¹, Rajwinder Riar¹, Leone Ferrari¹, Veronica Massawe², Mahamane Rabilou Abdou³, Monika Messmer¹, Amritbir Riar¹

¹Research Inst. of Organic Agriculture (FiBL), Switzerland ²SWISSAID Tanzania, Tanzania ³SWISSAID Niger, Niger

This study examines the motivations of farmers in Tanzania and Niger and their influence on the choice of agricultural production systems. By exploring factors such as improving soil quality, achieving better yields, sustainable production, utilising available resources, enhancing social reputation, gaining family appreciation, preparing for farm succession, reducing reliance on external inputs, minimising risks, and obtaining healthy food, we aimed to understand how these motivations impact farmers' decisions to adopt organic, conventional, or integrated farming practices. Data were collected from 392 Tanzanian and 684 Nigerien farmers using Kobo Toolbox and analysed using R software, with Principal Component Analysis (PCA) conducted separately for each country to assess variations in farmers' motivations. The PCA results revealed significant differences between the two countries. For Tanzanian farmers, the PCA explained 88.1% of the variation in motivations, indicating a strong alignment between their motivations and the choice of organic farming. This suggests that organic practices in Tanzania are closely linked with desired agricultural and economic outcomes, driven by the motivations studied. In contrast, in Niger, the PCA accounted for 63.5% of the variance in motivations, showing a weaker correlation between motivations and the adoption of organic farming, pointing to potentially different influencing factors or challenges. The study highlights the importance of understanding region-specific farmer motivations to tailor agricultural policies and interventions effectively. Such insights are vital for promoting sustainable practices that align with farmers' goals and regional needs, thereby enhancing productivity, environmental sustainability, and rural livelihoods. This approach not only supports the farming community but also contributes to global efforts to tackle challenges like food security and climate change.

Keywords: Farmers, motivations, perceptions, principal component analysis, sustainable agriculture

Contact Address: Tanay Joshi, Research Inst. of Organic Agriculture (FiBL), International Cooperation, Frick, Switzerland, e-mail: tanay.joshi@fibl.org

Perception of agroecological performance of dairy farms by smallholders in Mexico

Dalia Andrea Plata-Reyes¹, Dante Pizarro Paz², Carlos Galdino Martínez-García¹, Michel André Wattiaux², Carlos Manuel Arriaga-Jordán¹

¹Universidad Autónoma del Estado de México, Instituto de Ciencias Agropecuarias y Rurales, Mexico

²University of Wisconsin-Madison, Dept. of Animal & Dairy Sciences, United States

The Tool for Agroecology Performance Evaluation (TAPE) is a novel FAO tool developed to collect data on how the 10 Elements of Agroecology (EA): Diversity, Synergies, Efficiency, Recycling, Resilience, Culture & Food Traditions, Co-creation & Sharing of Knowledge, Human & Social Values, Circular & Solidarity Economy, and Responsible Governance can contribute to sustainable agricultural and food systems. One of the steps of TAPE involves a participatory analysis of survey results with participant farmers during a workshop. The goal of this study was to determine the perception of smallholder dairy farmers in regard to the likelihood of change in agroecological practices on their farm and key actors responsible for these changes. We conducted a 2-hour workshop in Aculco, Mexico (n = 12 participants). Using a Likert scale from -2 (Very unlikely) to 2 (Very likely), farmers rated their likelihood of changing practices related to the 10 EA. To identify key actors responsible for these changes, farmers were tasked with allocating 10 points among 5 options: individual, community, or government at the municipal, regional, or central level. Median values were analysed with the Mann-Whitney U test. No significant differences were detected for the likelihood of change in any EA (All $p \ge 0.36$). In addition, survey participants rated themselves as the primary agent of change compared to other key actors (p < 0.05). In other words, farmers overwhelmingly agreed that they were the main actors responsible for implementing changes. In evaluating the workshop, participants indicated a high degree of interest to learn more about agroecological practices. This study provides smallholder farming communities a voice to chart their own future.

Keywords: Agroecological, small-scale dairy systems, sustainable food

Contact Address: Dalia Andrea Plata-Reyes, Universidad Autónoma del Estado de México, Instituto de Ciencias Agropecuarias y Rurales, Instituto Literario # 100 Col. Centro, 50000 Toluca, Mexico, e-mail: daplatar@uaemex.mx

Barriers to agroecological transition of coffee-based farming systems in the central highlands of Vietnam

Tuan Ha 1, Eric Rahn 2, Sven Anders 3, Giang Pham 1, Khanh Le 4, Cornelis $$\rm Swaans^1$$

¹The Alliance of Bioversity International & CIAT, Vietnam

²The Alliance of Bioversity International & CIAT, Colombia

³University of Alberta, Dept. of Resource Economics and Environmental Sociology, Canada

⁴*The University of Western Australia, Centre of Environmental Economics and Policy, Australia*

The expansion of export commodity production systems across Vietnam's Central Highlands (VCH) has come at significant environmental costs for communities. Land degradation stemming from unsustainably intensive farming practices particularly threatens the livelihoods of ethnic minority groups. The EU's deforestation regulation ((EU) 2023/1115) that restricts the import of coffee if sourced from areas affected by forest degradation further calls for urgent interventions to reverse unsustainable practices.

This study investigates barriers and opportunities to the adoption of agroecological (AE) interventions of VCH cropping systems to combat land and forest degradation practices. An adapted Rural Household Multi-Indicator Survey (RHoMIS) was conducted during 2022–2023 with 724 representative coffee farmers across 4 districts of Lam Dong and Dak Nong. The findings were validated and enriched through stakeholder interviews, workshops, and farmer focus groups.

The analysis reveals diverse yet limited knowledge of sustainable practices such as intercropping, integrated soil fertility management, responsible use of agrochemicals and water use for irrigation across ethnic groups, socioeconomic status, and literacy levels. Barriers to AE adoption also stem from ineffective policies and underfunded extension systems. Market-based and policy incentives to transition farms to AE practices are lacking. Limited access to cooperative structures and supply-chain linkages and their related benefits of cost savings and market premiums among marginalised farmers hinder the adoption of AE practices. The high financial investments for intercropping and/or agroforestry constitute disincentives for many smallholder farmers. Additionally, recent production requirements (e.g., pest control) for durian exports pose obstacles to the participation of marginal farmers in lucrative specialty crop export markets. Barriers to AE stand against increasing buyer demands for eco-friendly production supported by government

Contact Address: Tuan Ha, The Alliance of Bioversity International & CIAT, Km 2 pham van dong st bac tu liem district, 11900 Hanoi, Vietnam, e-mail: tuan.ha@cgiar.org

initiatives to mitigate forest degradation and to restore natural forest land using AE practices. Moreover, market and policy support for AE transition is complemented by donor-funded programs. The presence of these varied developments serves as strong rationale for context-specific interventions including tailored support policies and extension programmes to facilitate the widespread adoption of AE practices especially by marginalised farmers.

Keywords: Challenges, climate-resilient production practices, ethnic minorities, farming practices, household economics, literacy level

Nutrient release from litter under five cacao cultivation systems in Sara Ana (Alto Beni Bolivia)

Isabel Morales-Belpaire¹, Karen Losantos-Ramos², Patricia Amurrio-Ordoñez², Stéphane Saj³

¹Universidad Mayor de San Andrés, Institute of Molecular Biology and Biotechnology, Bolivia

²Universidad Mayor de San Andrés, Inst. of Ecology, Bolivia

³Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland

Cocoa serves as a primary source of income for smallholder farmers in the Alto Beni region (Bolivia). Given its ability to thrive in low-light conditions, it is well adapted for cultivation within agroforestry systems (AFS). Cacao's phenotypic plasticity also allows for successful growth under full-sun conditions, often resulting in higher yields compared to AFS, particularly in the first years. However, the longevity of full-sun monocultures tends to be shorter compared to AFS. Cultivating cacao within AFS can offer various benefits and ecosystem services, including nutrient cycling, which may reduce the need for external fertilisers. Nutrient cycling encompasses litter decomposition processes and is influenced by many factors such as the species and diversity of shade trees, management practices, microclimatic conditions, and soil type. Within the framework of the long-term SysCom cacao trial in Alto Beni, our study aimed to determine the effects of five different cacao cultivation systems on leaf-litter decomposition and nutrient release. We placed litterbags containing cacao leaves or mixtures of cacao and shade tree leaves across the different cultivation systems. Two mesh sizes were used for the litterbags: 2 mm mesh that allowed the entry of mesofauna and 0.2 mm mesh that excluded them. After 4, 8, and 12 months of decomposition, we collected the litterbags for chemical analysis. On average, after 4 months of decomposition, there was approximately a 40% loss of carbon, 30% loss of nitrogen, 65% loss of phosphorus, and 70% loss of potassium. By 12 months, samples lost on average 82 % of carbon, 60 % of nitrogen, 95 % of phosphorus, and 98 % of potassium. The percentage of cellulose in the samples remained relatively constant, while lignin content tended to increase. There was no significant effect of the cultivation system on decomposition. Surprisingly, no significant difference in the decomposition of samples that only contained cacao leaves compared to those with leaf mixtures was observed. At four months, carbon and nutrient contents in larger mesh litterbags were significantly lower than in smaller mesh litterbags, possibly due to presence of mesofauna, but also to other processes such as easier leaching from large mesh bags.

Keywords: Agroforestry, litter decomposition, nutrient cycling

Contact Address: Isabel Morales-Belpaire, Universidad Mayor de San Andrés, Institute of Molecular Biology and Biotechnology, Calle 27 s/n campus universitario cota cota, 0000 La Paz, Bolivia, e-mail: imorales@fcpn.edu.bo

Assessing farmers' attitudes toward organic fertilisers in Kiambu and Kirinyaga counties, Kenya

Grace Tete Mensah¹, Kinyili Mutua², M. Rashid Mwajita¹, Catherine Ngamau¹, Aggrey Nyende¹, Goetz Uckert³, Stefan Sieber³

¹Jomo Kenyatta University of Agriculture and Technology, Dept. Horticulture and Food Security, Kenya

²Jomo Kenyatta University of Agriculture and Technology, Dept. of Agriculture and Resource Economics, Kenya

³Leibniz Centre for Agric. Landscape Research (ZALF), Germany

Agricultural production is hampered by factors such as low productivity resulting from a decline in soil fertility and soil health. Organic fertiliser is recognised as an agricultural approach that can reduce direct production expenses, improve environmental advantages, and increase crop yields. Despite the benefits organic fertiliser poses, its utilisation is low among smallholder farmers in Kenya. This is due to the risk of using contaminated raw materials, and insufficient material for decomposition among others. However, some entities are producing certified organic fertilisers and selling them to farmers. Yet, farmers' attitudes towards these fertilisers are not known. To enhance the utilisation of organic fertilisers, the practice must align with farmers' attitudes. Therefore, this study established the attitudes of smallholder farmers toward organic fertiliser utilisation. A farmer who has a positive attitude may influence fellow farmers to use the product. The research was carried out in the regions of Mwea and Githunguri subcounties in Kenya, where the production of organic fertilisers, such as bokashi and safi sarvi, takes place. The study employed purposive and simple random selection procedures to choose a sample size of 109 farmers. A structured questionnaire was used to collect data on farmers' socio-economic characteristics and attitudes. Attitude was captured using fourteen (14) statements on a 5-point Likert scale, ranging from strongly disagree to strongly agree. Descriptive statistics were used to identify the attitudes of farmers. Results showed that there were more women (58.7%) involved in farming activities than men because farming was the main occupation. In terms of attitudes, 11 out of the 14 statements were scored positively on the Likert scale (agree and strongly agree) revealing that the attitudes of the farmers towards organic fertilisers were positive. The study concluded that farmers had positive attitudes toward organic fertilisers, yet there is a need to improve sensitisation of organic fertilisers among farmers to increase their utilisation.

Keywords: Attitudes, Kenya, organic fertiliser, smallholder

Contact Address: Goetz Uckert, Leibniz Centre for Agric. Landscape Research (ZALF), Müncheberg, Germany, e-mail: Goetz.uckert@zalf.de

Effective method of acclimatisation for *in vitro* propagated hybrid coffee seedlings (*Coffea arabica* L.) at Jimma, southwest Ethiopia

HABTAMU SEYOUM ARAGAW

Ethiopian Institute of Agricultural Research, Plant Biotechnology, Ethiopia

Coffee is an important crop and a major source of foreign currency in Ethiopia. The majority of smallholders, who normally hold the lion's share of coffee production in the country, rely on the crop for their livelihood. Coffee productivity does not improve despite increasing production, consumption, and marketing. Despite of major emphasis given, Ethiopia's coffee sector has not transformed and according to the central statistic authority, the national average productivity is around 7 kg ha⁻¹. This can be improved by adopting climate adaptive, disease resistant high vielder and superior quality coffee varieties of hybrids along with their improved agronomic practices. However, its availability has been a limitation to producers. JARC plant tissue culture laboratory therefore optimising a protocol for mass propagation and dissemination of F1 hybrid coffee clones. Following successive somatic embryogenesis processes, in vitro-produced plantlets need to be hardened under greenhouse conditions before it's dispatched to the field. To this effect, we evaluated different soil substrates under room temperature as the requirement for primary and secondary acclimatisation. The experiment was composed of three treatments, including top soils, sand soils, & the mixture (top soils + sand+compost), at ratios 100, 100 & 67:33:33 respectively. The results show that there is a significant difference among the treatments in terms of plant survival and overall seedlings performances. Using sand gave the best result in all materials being applied such as bricks had a survival rate (of 85%), metal boxes (90%) & plastic pots (>95%), while using only top soils it was 70% survival and their mixtures i.e. substrate with 2:1:1 had a survival ranged between 74–87 % depending on the materials applied for hardening off. From this greenhouse experiment, it is possible to optimise an *ex-vitro* condition for proper coffee seedling hardening and handling using locally available resources. Thus, sand appears to be the best substrate for the primary acclimatisation of somatic seedlings. Applying proper soil mixtures could increase the efficiency of hybrid coffee multiplication through tissue culture techniques.

Keywords: Acclimatisation, arabica coffee, somatic embryogenesis, tissue culture

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

No-tillage and cover crop practices for the agroecological transition of rainfed Tunisian olive groves

Olfa Boussadia¹, Hatem Zgallai², Amel Ben Hamouda¹, Marius Hobart³, Pierre Ellssel⁴, Stéphanie Saussure⁵

¹Olive Institute (IO), Tunisia

²National Institute for Agronomic Research (INRAT), Tunisia

³Leibniz Inst. for Agricultural Engineering and Bioeconomy (ATB), Agromechatronics, Germany

⁴BOKU University, Dept. of Crop Sciences, Austria

⁵Natural Resources Institute Finland (LUKE), Finland

Climate change, severe soil degradation and low soil fertility, exacerbated by inappropriate agronomic systems, have led to unbalanced, less resilient and increasingly unsustainable farming systems in North Africa. This has had serious consequences in socio-economic and environmental terms. In order to address these problems and to improve the agronomic performance of olive groves, we tested the effect of different agricultural soil management practices (tillage, no-tillage and cover crops) on soil properties, olive tree nutrient dynamics and olive/oil production. The study is carried out at two experimental sites (Toukaber 36°42'22"N 9°30'38"E, Beja Governorate, and Jammel 35°38'27.5"N 10°41'24.2"E, Monastir Governorate, Tunisia) during the cropping seasons of 2022 and 2023 ('on' and 'off' years). The sites have been selected according to the rainfall gradient (500 mm to 300 mm). The experimental design followed a Randomised Complete Block Design (RCBD) with four treatments (tillage, no tillage, favabean intercropping and fenugreek intercropping) for both sites and three and five replications in Toukaber and Jammel, respectively. The main results showed that, under rain-fed conditions, the absence of tillage and the intercropping with leguminous crops increase the organic matter (OM) and nitrogen (N) content of the soil. In addition, intercropping can be an essential component to improve the nitrogen nutrition of olive trees by increasing the leaf nitrogen (leaf N) content. Either by increasing OM or by improving soil and leaf N, olive yield was significantly improved. It can be concluded that the tested agroecological practices showed an improvement in soil fertility parameters and olive productivity, but it is important to note that no tillage and the choice of cover crop need to be carefully selected according to soil type and the local rainfall.

Keywords: Cover crop, leaf nitrogen, no tillage, organic matter, Tunisia

Contact Address: Olfa Boussadia, Olive Institute (IO), 14 Rue ibn Khouldoun, 4061 Sousse, Tunisia, e-mail: io.olfa.boussadia@gmail.com

Social perception of smallholder farmers on the uptake of organic fertilisers in Kigumo subcounty

Dennis Njoki¹, M. Rashid Mwajita¹, Anthony Sije¹, Aggrey Nyende¹, Goetz Uckert², Stefan Sieber²

¹Jomo Kenyatta University of Agriculture and Technology, Dept. of Horticulture and Food Safety, Kenya

²Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

Declining soil fertility is a serious problem across sub-Saharan Africa, and a persistent constraint to agricultural production especially in low potential areas, thus posing a major threat to food security and rural livelihoods. The organic fertiliser (OF) has a huge potential impact on reversing the deteriorating soil fertility and improving soil health. The adoption of organic fertilisers has been low due to overreliance on synthetic fertilisers. This study was done to analyse social perception of smallholder farmers on the uptake of OF for crop production. The survey was conducted in Kigumo-Muranga county in Kenya. A sample of 100 smallholder farmers in a survey, was presented with 20 statements divided in four sections and ranked them on a likert scale of 5. Collected data was analysed using SPSS. On cost of, the likert scale weighted mean was 4.08 which was more positive with an average standard deviation (SD) of 0.6593. This showed that the cost of organic fertiliser strongly influences its uptake by smallholder farmers. On the crop produced with OF, the weighted mean -3.98 and SD -0.7527, which showed that the farmers perceived the crop produced with OF as of high quality and safe for consumption which greatly influences the uptake of organic fertilisers. On OF Impact on Environment, the mean was 3.805 and SD - 0.8225, which showed that it has less influence on farmers' adoption OF. On Credit /Political Good-Will, the mean was 3.37 and the SD was 0.92433, which revealed that credit and the political good-will does not greatly influence the uptake of by smallholder farmers. These results revealed that the agroecology policy in Murang'a county is not yet known and the county budget in place to support the policy is not effective. The smallholder farmers perceive cost and quality of produced from crop grown with OF as the biggest contributing factors for its adoption. It is suggested that sensitizing on Murang'a Agroecology Policy through effective media at a county level will promote uptake of OF by smallholder farmers. Meanwhile, allocating more financial assistance and subsidy on organic fertilisers will greatly promote its adoption.

Keywords: Kigumo subcounty, organic fertiliser (commercial and homemade), smallholder farmers, social perception

Contact Address: Goetz Uckert, Leibniz Centre for Agric. Landscape Research (ZALF), Müncheberg, Germany, e-mail: Goetz.uckert@zalf.de

Agroforestry for reconciling ecosystem functions, biodiversity and productivity

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Agroecological approaches in the dryland agroforestry systems of West African Sahel

Harun Cicek¹, Moussa Gnissien², Souleymane Kone³, Ndèye Maguette Hane⁴, Salouma Macalou⁵, Hassna Founoune⁴, Kouyaté Aliou Badara³, Yelemou Barthelemy⁶, Laurent Cournac⁷, Kalifa Coulibaly²

¹Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland ²Université Nazi Boni, Lab. d'Etude et de Recherche sur la Fertilité du Sol, Burkina Faso ³Inst. Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou, Mali

⁴Institut Sénégalais de Recherches Agricoles (ISRA), Senegal
⁵Institut d'Economie Rurale (IER), Mali
⁶Institut de l'Environnement et de Recherches Agricoles (INERA), Burkina Faso
⁷Université de Montpellier, IRD, CIRAD, INRAE, Institut Agro, France

The application of agroforestry practices can reduce soil degradation and improve yields in drylands. Agroforestry parks in West Africa's Sahel region are diverse, given the many needs that people have to satisfy and, above all, the fact that each species can play a different role. They depend on the socioeconomic, ecological and soil fertility benefits that agroforestry parks provide for local populations. Here we report on promising co-created farming systems performance in Mali, Senegal and Burkina Faso in terms of crop productivity and soil quality. The assessment of existing knowledge regarding the use of shrub/tree species in agricultural systems, as well as the identification of crop-shrub interactions appropriate to local contexts, identified a list of species that could be integrated into the design of locally relevant systems. In all three countries, a variety of on-station and on-farm trials have been set up to study the impact of tree and shrub species on soil properties, crop yields. We report on initial findings of some of the 16 on-farm and 10 on-station trials that were set up from 2020 to 2023. Most of the trials involved various ways of using shrubs as fertility amendment and testing several shrubs for their establishment, biomass productivity, quality and mineralisation/fertility potential. Productivity gradient of crops in relation to the distance to shrubs, their crop yield, dry matter productivity, harvest index, and water use efficiency are assessed. For shrubs, the observations and measurements include their pruning frequency and include dry matter productivity and rate, leaf/stem ratio. Our initial results show that using prunings of the shrubs can significantly increase sorghum yield. When some fertiliser is added the effect can be more significant. Mulched soils (with shrub biomass) have the best soil structure and the highest infiltration rate, meaning greater capture of rain water for the

Contact Address: Harun Cicek, Research Inst. of Organic Agriculture (FiBL), International Cooperation, Ackerstrasse 113, 5070 Frick, Switzerland, e-mail: harun.cicek@fibl.org
crops. Soil moisture content increased in plots where various shrub mulches were applied in singly or in a mixture. Our results will help farmers to rely on their local resources, reduce their external synthetic inputs and costs, improve their soil health and fertility, increase crop productivity and improve their livelihoods.

Keywords: Agroecology, agroforestry, drylands, mulching, Sahel, shrubs, West Africa

Adoption and impact of agroforestry on household food security among farmers in Ghana

EMMANUEL FRIMPONG, ENOCH OFORI NTOW, SAMUEL OWUSU Inst. of Agriculture, Education and Rural Development Research, Ghana

Agroforestry is becoming more and more recognised as a key tactic for mitigating and adapting to climate change. The usage of fertiliser trees in particular has been pushed as a technique that increases the availability of nutrients for crop production and, through nitrogen fixation, improves soil fertility. There is a dearth of solid information regarding fertiliser tree effects in smallholder farming situations, even if most of the evidence is based on correlational analysis and on-farm tests. This study examines how fertiliser trees, such as Faidherbia albida and Gliricidia sepium, affect the food security of households. To thoroughly examine the effects of adoption, 500 farmers in Ghana were interviewed and endogenous switching regression was used. The value of food crops rises by 56 % when fertiliser trees are adopted, according to econometric data. When the impacts are broken down by land ownership strata, it becomes clear that farmers with smaller farms-up to three acres-realise the largest gains. Moreover, the use of fertiliser trees along with better maize seeds greatly raised the value of food harvests. With the use of cutting-edge analytical techniques, this study provides initial insights into a growing body of research on the quantitative evaluation of agricultural interventions like agroforestry practices. To fully realise the potential of agroforestry in enhancing soil fertility and household food security, the study offers some policy insights and suggests that future research be planned around development initiatives that take into account fine-scale variation in the social, economic, and ecological context of farmers. This will improve uptake and adaptation.

Keywords: Agroforestry, farmers, fertiliser trees, food security

Contact Address: Emmanuel Frimpong, Inst. of Agriculture, Education and Rural Development Research, P.O.Box up 982 KNUST, Kumasi, Ghana, e-mail: efrompong2020@gmail.com

Examine farmer's perception of integrating cattle rearing into cashew-crop agroforestry, with emphasis on farmers' socioeconomic status, resource management, carbon and nutrient dynamic: Evidence from households using tape

Zinsou Bernus Djigbe¹, Rodrigue V. Cao Diogo², Pierre Gbenoukpo Tovihoudji³

¹University of Parakou, Fac. of Agronomy (UP/FA), Benin

²University of Parakou, Dept. of Sci. and Techn. of Animal Prod. and Fisheries, Benin

³University of Parakou, Dept. of Crop Production, Benin

The study focuses on promoting sustainable agricultural practices in cashew agroforestry systems in Benin's Tchaourou Sud-Borgou Zone. Integratedcrop-livestock-forestry (ICLF) systems are being promoted as a means of sustainable agricultural intensification. However, there is a lack of evidence regarding the resilience of cashew-based agroforestry systems, especially in cashew high-production regions where soil fertility loss is prevalent. To address this, the study selected 208 mixed farms in four villages in Tchaourou. The farms integrated cashew plantation intercropping and livestock into their production systems. The farms were assessed using the FAO-designed TAPE (Tools for Agro-ecology Performance Evaluation) tool to analyse their agroecological performance as well as to evaluate farm diversity.

The results showed that overall, the farms had low agro ecological performance, with only three out of ten dimensions meeting or exceeding the threshold of 50%. The agroecological performance did not significantly differ between survey villages. The study identified three main classes of farm diversity: 22 farms in an incipient transition phase (10.57%), 2 agroecological farms (0.96%), and 184 non-agroecological farmers (88. 46%). These findings highlight opportunities for agro-ecological transition within each identified cluster.

Furthermore, our research also aimed to examine the extent of carbon sequestration within ICLF systems, to accomplish this, we utilised carbon estimation methods proposed by the TAPE tool. Surprisingly, our findings indicated that ICLF farming systems exhibited a higher capacity for carbon sequestration compared to non-ICLF farming systems. It is worth noting that effectively managing this carbon sequestration through the consideration of ICLF spatial planning can yield significant economic value.

Keywords: Agro farmer, agroforestry, farming system, grazing cattle, ICLF

Contact Address: Zinsou Bernus Djigbe, University of Parakou, Fac. of Agronomy (UP/FA), 40 Ilot, Parakou, Benin, e-mail: djigbezinsou7@gmail.com

Long-term economic viability of different coffee intercropping systems in the central highlands of Vietnam

Giang Pham¹, Sven Anders², Khanh Le³, Tuan Ha¹, Eric Rahn⁴, Cornelis Swaans¹

¹The Alliance of Bioversity International & CIAT, Vietnam

- ²University of Alberta, Dept. of Resource Economics and Environmental Sociology, Canada
- ³*The University of Western Australia, Centre of Environmental Economics and Policy, Australia*

⁴The Alliance of Bioversity International & CIAT, Colombia

The Central Highlands of Vietnam (CHV) is the biggest Robusta coffee (*Coffea canephora*) producing region globally. However, climatic and market volatilities are increasingly challenging the predominantly smallholder farmers.

While coffee monocropping is the dominant production system, different intercropping systems have become an interesting way to manage risks and increase land use efficiency. Yet, the widespread adoption remains limited due to costly establishment investment barriers.

This study conducts detailed Net Present Value (NPV) analyses of spatially targeted coffee-based farming system interventions aimed at increasing income resilience and reducing pressure on crop area expansion into forests across four districts in Lam Dong and Dak Nong of the CHV. Consultation with stakeholder groups and household surveys with 510 representative coffee farmers were conducted in 2023, followed by validation workshops with local stakeholders to verify crop yields, prices, input costs, etc. NPV models were specified to predict the economic performance of four stakeholder-prioritised coffee intercropping systems with durian, macadamia, persimmon, or *Michelia tonkinensis* A. Chev over a 25-year horizon against coffee monocropping. NPV and annual farm cash-flows were modeled using Monte Carlo simulations considering uncertainties in Gompertz tree yield curves, pest and disease risks, establishment and operational costs, crop prices, and discount rates.

Simulation and sensitivity analyses highlight positive farm-level profitability of intercropping interventions relative to coffee monoculture. When revenue and cost uncertainties are considered, at least 60 % of farm households would earn positive economic benefits over 25 years. While the initial cost of establishing intercropped trees is a significant barrier, the optimal timing of planting within the coffee lifecycle can mitigate negative farm cash-flow effects.

Contact Address: Giang Pham, The Alliance of Bioversity International & CIAT, Km 2, Pham Van Dong St, Bac Tu Liem District, 11900 Hanoi, Vietnam, e-mail: G.Pham@cgiar.org

Already marginal and ethnic minority households may require financial support to maintain community living standards over the model period. Importantly, diversification through intercropping improves economic resilience by buffering periods of low coffee prices and the cost of coffee replanting. This paper shows that sustainable, natured-based interventions can yield positive economic outcomes for farmers while increasing land use efficiency, thus lowering pressures of natural forest encroachment. Access to financial services with favourable terms may be needed for broad uptake of sustainable coffee practices in Vietnam.

Keywords: Deforestation-free coffee, ethnic minorities, household livelihood, Monte Carlo simulations, net present value analysis, tree intercropping

Plant available water content and water use in a fruit-crop agroforestry practice on sloping land

Huu Thuong Pham, A. Sigrun Dahlin Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden

Fruit tree cultivation has expanded strongly on sloping lands of Vietnam, often in agroforestry systems. Agroforestry has been proposed as an alternative to sole-cropping systems based on benefits such as soil conservation, biodiversity, and increasing farmers' livelihood. However, there are constraints in agroforestry with several systems under-performing compared with expectations, and competition for water between system components may be one reason. Water is a vital resource used by all system components, and strongly affects yields and productivity. Understanding the distribution and use of plant-available water in soils is important to manage competition for water and to redesign the systems and their management. Our study assessed the distribution of plant-available water in a fruit tree-maize agroforestry system and compared it with a control sole-maize system. The agroforestry system included longan, mango, maize, and guinea grass planted in rows along the contour and was established in 2017. The trial was designed as Complete Randomised Block Design with 4 replicates on sloping land in the mountainous Northwest Vietnam. Nine zones were defined at different distances from the tree rows; maize zones 1 to 4 upslope of the tree rows (being zone 5), zones 6 (being grass strips), and maize zones 7–9 downslope of the trees. Soil water was monitored using gravimetric samples at four maize growth stages including 3-4 leaves, 6-7 leaves, 10-11 leaves, and silking in 2022 and 2023. Additional samples were collected before and after the maize season. Soil water evaporation and infiltration rates were also measured in 2023. Our results show that the agroforestry system stored more water than the sole-maize system, resulting in higher plant available water in the soil around tree rows. There was, however, no significant difference between soil water content in the maize zones upslope and downslope of the tree rows. Water competition was found at some sensitive periods as a consequence of low plant-available water in the soil profile, suggesting that this limited maize yield. Changing component species and/or management approaches are needed for system sustainability. An additional study on nutrient competition would complement.

Keywords: Water use efficiency, agroforestry, available water content

Contact Address: Huu Thuong Pham, Swedish University of Agricultural Sciences, Crop Production Ecology, Ekologicentrum ulls väg 16, 70507 Uppsala, Sweden, e-mail: huu.thuong.pham@slu.se

Effects of different coffee cropping systems on nutrient status and yield of arabica coffee

Thanchanok Yosen¹, Nipon Mawan², Nuttapon Khongdee², Krit Khetanun³, Yupa Chromkaew⁴

¹Chiang Mai University, Central Laboratory, Thailand

²Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand ³Chiang Mai University, Agricultural Innovation Research, Integration, Demonstration and Training Center, Thailand

⁴Chiang Mai University, Dept. of Plant and Soil Science, Thailand

The current trend of increasing coffee consumption has led to a higher demand for coffee beans. As a result, in Thailand, farmers are increasingly turning to coffee cultivation with different cropping systems, including coffee monoculture, coffee agroforestry (coffee intercropped with forest trees), and coffee intercropped with economic fruit trees such as mango and banana. Therefore, this study aimed to study the nutrient levels in the soil, leaves, and coffee yield under different coffee cultivation systems. The soils were randomly sampled from three different coffee cropping systems, including 1) coffee monoculture, 2) coffee agroforestry, and 3) coffee cultivated with economic fruit trees. Soil samples were analysed for some soil chemical properties. For plant nutrients, leaf samples were collected during the fruiting stage, while coffee yields were recorded at harvest. The results showed that the soil pH under coffee cultivation with economic fruit trees had the highest pH (6.10+0.07), which was significantly higher than the soil pH under coffee monoculture (5.74+0.10) and coffee agroforestry (5.72+0.08) (p < 0.05). However, there were no significant differences in the soil nutrient levels (N, P, K, Ca, Mg) and leaf nutrient levels among the different coffee cropping systems. Regarding the coffee yield, coffee monoculture had the highest yield at 16.81 ± 2.56 kg ha⁻¹, significantly higher than the yield of coffee cultivation with economic fruit trees $(7.62+2.16 \text{ kg ha}^{-1})$ and coffee cultivation with forest trees $(2.16\pm0.58 \text{ kg ha}^{-1})$. In the present study, a negative correlation was found between soil potassium and coffee yield, but no significant correlation was found between leaf nutrient levels and coffee yield.

Keywords: Coffee cultivation systems, coffee yield, leaf nutrient levels, soil nutrient levels

Contact Address: Yupa Chromkaew, Chiang Mai University, Dept. of Plant and Soil Science, Huay Kaew Road, Muang District, 50200 Chiang Mai, Thailand, e-mail: yupa.c@cmu.ac.th

Diachronic study of the Dallol Maouri *Borassus aethiopum* Mart. parkland in the south-western Niger employing remote sensing

DJIBRIM ABDOULAYE¹, MARTIN WIEHLE², LARWANOU MAHAMANE¹

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 grove, a wetland of approximately 30,000 ha, experienced once excessive exploitation of palm wood appreciated for construction, especially in urban areas. The awareness of its degradation in the 1990s led to several restauration interventions. This ecosystem is a hotspot for biodiversity in semi-arid regions but also a socio-economic backbone for local livelihoods. However, alongside these restoration efforts, certain practices like fraudulent logging and the effect of wind and floods, undermine this progress and threat its sustainability. Hence, we carried out a comparative study over time to better understand the evolution of this palm grove and derive suitable future management strategies. To conduct this study, an unsupervised K-means classification method with QGIS software was applied to Landsat satellite images from the years 1987, 2003 and 2022, whose data was previously subjected to a principal component analysis. Five classes were identified: flooding area, area with high-, moderate- and low-density of Borassus and bare soil. Changes in land use were obtained by change detection method. For validation, 375 training points were used from virtual visit, i.e. 75 points per class. The overall accuracy and kappa values were 80.1 % and 0.71, respectively. During the regeneration interventions between 1987–2003, we found that the palm grove experienced an overall increase in moderate (2,229 ha) to high (794 ha) density areas of Borassus. Later between 2003 to 2022 and despite a continuation of regeneration actions, the palm grove lost an overall 1,415 ha, or 30% of its area with moderate density of Borassus. In addition, the Bana-tela and Tousseye strata, both lost around one hundred (100) hectares, or 32% of their highdensity zone of Borassus. We also noted an expansion of the flood zone (1,209 ha) for all five strata of the Borassus grove. This study shows that despite regeneration actions, from 2003 to the present, moderate- and high-density areas of Borassus are increasingly transformed into areas with scattered palm trees, caused by natural phenomena and anthropogenic activities. Future development planning should focus on these land cover maps for more targeted actions and proceeding on a case-by-case basis.

Keywords: Borassus grove, evolution, unsupervised K-means classification

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

Revealing yield drivers in Sulawesi cocoa agroforestry: The primacy of farm management over shade levels

Thao Pham¹, Eric Rahn², Iskandar Zulkarnaen Siregar³, Suria Darma Tarigan³, Ulfa Adzkia^{4,3}, Miftah Rahman³

¹The Alliance of Bioversity International & CIAT, Asia Hub, Vietnam

²The Alliance of Bioversity International & CIAT, Colombia

³Bogor Agricultural University (IPB), Indonesia

⁴University of West Sulawesi, Fac. of Forestry, Indonesia

Agroforestry has received increasing attention from the cocoa sector as a promising practice to simultaneously address multiple production and sustainability goals. Several studies suggested that at certain shade levels, there are opportunities to significantly increase cocoa yield while improving soil fertility, climate change mitigation and adaptation, as well as supporting farmer's livelihoods. Nevertheless, the effects of shade trees on cocoa have been a central debate for practitioners. Moreover, the definition of cocoa agroforestry (CAFS) is inconsistent across different locations and contexts, since relying on a common indicator such as the number of shade trees could result in differing shade levels depending on species types and crown characteristics. This research aims to characterise CAFS systems on 200 farms across Sulawesi, Indonesia. Combining field-level data from farmer surveys, vegetation assessment, and pod counting for yield estimation, carbon stocks and greenhouse gas emissions are estimated. We identified four CAFS typologies in Sulawesi, which are 1) cocoacoconut; 2) cocoa-Gliricidia sp.-pepper; 3) mixed CAFS with low carbon value; and 4) mixed CAFS with high carbon value. Cocoa yield did not show significant differences among CAFS typologies, yet considerable variation existed within each typology. A generalised linear model with a Gamma distribution and log-link indicated that cocoa yield was affected by farm management factors rather than shade level or planting density of shade trees. The number of productive trees, combination of clones, and pruning were significant yield drivers. Interestingly, the effects of application of insecticides and inorganic fertilisers were only significant on cocoa yield when pruning was practised. To increase aboveground carbon stocks, different strategies could be tailored per typology; for example, mixed CAFS with low carbon value could enhance carbon sequestration by gradually replacing unproductive mature plants with new ones and introduce additional big shade trees with high wood density along the boundary. Through all typologies, effective use of nitrogen fertilisers would reduce greenhouse gas emissions. Findings from this research provide valuable insights for decision-making and design of effective CAFS in Sulawesi and beyond. It highlights the need for comprehensive baseline data at the farm level and the importance of tailoring recommendations to local contexts.

Keywords: Cocoa agroforestry, cocoa Sulawesi, cocoa yield

Contact Address: Thao Pham, The Alliance of Bioversity International & CIAT, Asia Hub, Hanoi, Vietnam, e-mail: thao.pham@cgiar.org

Land use alters nocturnal insect communities and their contribution to coffee pollination in India's western Ghats

Rama Narayanan Harihara Subramanian 1, Smitha Krishnan 2, Anand M $$\rm Osuri^3$

¹ETH, Zurich, Switzerland ²The Alliance of Bioversity International & CIAT, India ³Nature Conservation Foundation, India

Land-use change is a major driver of insect declines and can disrupt insectdriven ecosystem functions and services. It is well-established that insects contribute crucially to pollinating many major crop species, and that insectmediated crop pollination is sensitive to habitat and landscape factors. However, this understanding is largely shaped by research on diurnal pollinators and pollination, while nocturnal pollination by insects and the factors that influence it remain poorly understood for most crops. We examined nocturnal insect communities and nocturnal pollination of shade-grown robusta coffee (Coffea canephora) in a landscape with coffee agroforests and tropical forest remnants in the Western Ghats, India. Specifically, we compared a traditional polyculture-shade coffee agroforest and a 40+ year-old secondary tropical rainforest comprising patches of abandoned robusta coffee bushes and asked: (1) how do the abundance, diversity, and composition of nocturnal insects differ between coffee agroforest and secondary rainforest?; and (2) is coffee nocturnally pollinated, and does coffee nocturnal pollination differ between the secondary rainforest and the more intensively managed coffee agroforest? We observed nocturnal flying insects using illuminated screens (24 screen nights in each habitat) and conducted pollinator-exclusion experiments on coffee flowers - comprising day- and night-exclusion treatments, and controls - in the coffee agroforest and secondary rainforest. Nocturnal insect encounter rates were 21 % lower in the coffee agroforest than secondary rainforest, and Lepidoptera and Coleoptera genus-level compositions differed between the two habitats, but genus-level diversity was marginally lower (Lepidoptera) or substantially higher (Coleoptera) in agroforest than in rainforest. While flowers accessible to diurnal insects had the greatest pollination success in coffee agroforest (19%-24%) and rainforest (34%-60%), we found some evidence of nocturnal coffee pollination in the secondary rainforest, and none in agroforest. Our findings suggesting reduced abundances and altered community composition, but not diversity loss, of nocturnal insects in coffee agroforests aligns with previous findings on other taxa, and reiterate the conservation significance of traditional polyculture-shade coffee

Contact Address: Rama Narayanan Harihara Subramanian, ETH, Zurich, Zurich, Switzerland, e-mail: nram.efi@gmail.com

agroforests. Our study also presents preliminary empirical evidence that nocturnal insects have the potential to pollinate robusta coffee and complement and enhance diurnal pollination, but suggest that nocturnal coffee pollination is vulnerable to deforestation and land-use intensification.

Keywords: Agroforestry, Coleoptera, exclusion experiment, land-use change, Lepidoptera, plant-pollinator interactions, Robusta coffee, tropical forest

Shallow groundwater in sustainable agriculture and water management: Insights from Ghana's cocoa farming landscape

Johannes Herzog¹, Afia Sarpong Anane Gyebi², Junias Adusei-Gyamfi², Olufunke Cofie³, Jennie Barron¹, Michael Stockinger⁴, Seifu Admassu Tilahun³

¹Swedish University of Agricultural Sciences, Dept. of Soil and Environment, Sweden ²Kwame Nkrumah University of Sciences and Technology (KNUST), Dept. of Environmental Sciences, Ghana

³International Water Management Institute (IWMI), Ghana ⁴BOKU University, Inst. of Soil Physics and Rural Water Management, Austria

Shallow groundwater plays a pivotal role in both domestic water supply and the ongoing transformation of cocoa farms in Ghana, aimed at mitigating the impacts of climate change. Managing shallow groundwater requires understanding its interaction with surface water and role in transporting key nutrients like phosphorus (P) and nitrogen (N). This study was conducted in the sub-humid agroforestry-dominated Mankran micro-watershed, situated close to the city of Kumasi, in the upper Offin basins located in Ghana. Mankran, characterised by its relatively gentle slopes and an expected annual rainfall of about 1300 mm, predominantly comprises forested areas interspersed with cocoa plantations (70%), cultivated lands (24%), and minor built-up areas including mining and pre-urban zones (5%). Since June 2023, the study has involved the monitoring of seven shallow groundwater well levels, two stream flows, chloride concentrations in rainfall, streamflow, and groundwater, as well as dissolved N and P concentrations in both wells and streams. Analysis reveals that groundwater recharge can account for approximately 17% of seasonal rainfall (700mm) from June to December 2023 using chloride mass balance. The water table fluctuation (WTF) method leads to 75% of the seasonal rainfall within the watershed. The high variation mirrors the application of different methods each tied to its own uncertainties such as specific yield in the WTF approach. Streamflow represents only a fraction (about 9–14%) of the seasonal rainfall. Notably, mining activities significantly influence flow dynamics within the landscape. Nitrate concentrations in Mankran rivers peaked in June, whereas agricultural wells consistently displayed elevated concentrations throughout the rainy season, suggesting substantial leaching via subsurface flow. Similarly, phosphate concentrations in streams increased as the rainy period progressed, closely mirroring concentrations observed in wells and further indicating the dominance of subsurface flow. This study underscores the predominance of subsurface flow within

Contact Address: Jennie Barron, Swedish University of Agricultural Sciences, Dept. of Soil and Environment, Uppsala, Sweden, e-mail: jennie.barron@slu.se

the landscape and its pivotal role as a potential mechanism for affecting the WTF approach and transporting pollutants. Consequently, crops with deep root systems or a high tolerance to waterlogging may be advantageous in areas characterised by significant subsurface flow, particularly in the context of agro-food system transformation efforts.

Keywords: Agriculture, cocoa, groundwater, management, recharge

On-farm challenges and solutions for small-scale farmers to establish agroforestry: A case example from Cambodia

LILIAN BECK^{1,3}, CLAUDIA BIELING¹, A. SIGRUN DAHLIN², DELIA CATACUTAN³ ¹University of Hohenheim, Societal Transition and Agriculture, Germany ²Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden ³World Agroforestry Center, Cambodia

Agroforestry addresses food security challenges in tropical and subtropical countries by helping to adapt to climate change and improving soil fertility. To successfully disseminate the approach, it is crucial to understand how it is feasible for farmers to establish agroforestry. While many studies have shown the potential of agroforestry ecosystem services, few have looked at farmers' challenges in establishing such socialecological systems. To identify 1) on-farm challenges faced by farmers and 2) locally adapted solutions in a transdisciplinary manner, a longitudinal action research study was conducted 2021–2024 in northern Cambodia. A learning group of 24 small-scale farmers was engaged in implementing agroforestry. The farmers identified challenges and potential solutions through workshops and group discussions, and reflected on these in semi-structured interviews accompanied by farm visits. The action research revealed that although agroforestry has the potential to overall improve climate resilience, the challenges of implementing agroforestry are increasing due to climate change effects. Critical threats faced by farmers were extreme weather events like flash floods and prolonged drought periods which e.g., caused difficulties in establishing tree seedlings. These challenges were interrelated with land degradation, leading to stagnant water and increased pest problems. Potential solutions identified include integrating small-scale water management practices, mostly applied to balance extreme drought periods during the dry season and water oversupply during the rainy season. Solutions were adapted to the specific on-farm conditions integrating swale and canal systems, ponds, and micro watershed dams. However, a prerequisite for their implementation are investments and ensuring satisfying water quality, the latter addressed by using Azolla and Lemnoideae. Further, soil management was essential to increase water infiltration and improve soil and plant health. Adding organic matter and legume cover crops were the most important soil strategies. Soil improvement, diversification, integration of natural enemies and botanical pesticides were suitable pest management strategies. Identifying resilient plant species and short term companion species for income generation during establishment was also deemed a crucial strategy. Therefore, transdisciplinary identified solutions based on ecosystem services to overcome on-farm challenges imposed by climate change effects are crucial to establish agroforestry.

Keywords: Action research, agroecology, agroforestry, Cambodia, climate change

Contact Address: Lilian Beck, University of Hohenheim, Societal Transition and Agriculture, Schloss Museumsflügel, 70599 Stuttgart, Germany, e-mail: libk@posteo.de

Effect of zinc and boron on maize grain yield in agroforestry parklands of northern Ghana

Amisu Mohammed¹, Geronime Marlene Houeto², Vincent Avornyo¹, Deogratias Kofi Agbotui³, Andreas Buerkert³

¹University for Development Studies, Dept. of Soil Science, Ghana

²West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

³University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany

Nitrogen (N), phosphorus (P) and potassium (K) fertilisers have been widely used for maize (Zea mays L.) production by smallholder farmers in northern Ghana. NPK fertiliser-induced yield increases are on the decline which may be due to micronutrient deficiency in the typical open parkland systems dominated by shea trees (Vitellaria paradoxa C.F. Gaertn). Given paucity of information on micronutrient effect on maize agronomic performance in these parklands, this study was conducted to evaluate the effects of NPK and different micronutrients on maize yield. A split plot trial with shea tree area of influence considered as the main plot was delineated into canopy area (Zone A), 3 m away from canopy (Zone B), 10 m away from canopy (Zone C), and 20 m away from canopy (Zone D). Each zone was divided into sub plots where different types of fertiliser treatments were implemented; (i) farmer practice without fertiliser application (FP), (ii) sole NPK fertiliser (national recommended rate (NR): 60 kg N ha⁻¹, 13 kg P ha⁻¹, 25 kg K ha⁻¹), (iii) NR plus 7.5 kg Zn ha⁻¹ (NRZn), and (iv) NR plus 1.5 kg B ha⁻¹ (NRB) were applied. Results showed a significant interaction (p < 0.05) between zone and fertiliser application whereby grain yields were highest with NRZn in Zone D which was, 2.8-times larger than the FP in Zone A. Fertiliser use efficiency in NR plots was 6% lower than average fertiliser use efficiency of NRZn and NRB, however this difference was not statistically significant. In the absence of any substantial increase in grain yield and fertiliser use efficiency after application of micronutrients, we conclude that at the current yield levels Zn and B are not limiting farmers' maize yields in the study location.

Keywords: Fertiliser use efficiency, NPK fertiliser, shea tree parklands, soil micronutrients, tree crop interaction

Contact Address: Deogratias Kofi Agbotui, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Witzenhausen, Germany, e-mail: deogratiasagbotui@yahoo.com

Characterisation of shea tree and maize agroforestry parklands in northern Benin

Geronime Marlene Houeto¹, Amisu Mohammed², Deogratias Kofi Agbotui³, Jesse B. Naab¹, Vincent Avornyo², Andreas Buerkert³

¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

²University for Development Studies, Dept. of Soil Science, Ghana

³University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany

Maize (Zea mays L.) contributes significantly to food security and poverty reduction in northern Benin where it is traditionally grown within selectively thinned naturally regenerated shea trees (Vitellaria paradoxa C.F. Gaertn). These shea-maize parklands promote a biodiverse land use. Recent policies aiming at the intensification of these systems have been largely unsuccessful. This is largely because they are heterogenous in their management, tree structure and composition. Hence this study aimed at classifying them into groups. To this end a survey was used to collect socioeconomic and farm management information from 70 randomly selected farmers in Boukoussera and Wewe. Additionally farm assessments was undertaken to obtain information on tree density and richness and maize grain yield. Principal component analysis and hierarchical clustering were used to define three distinctive groups. Although tree species richness of Group 3 parklands was 40 % higher than of parklands in group 1 and 2, this difference was not statistically significant. Average tree density of parklands in Groups 1 and 2 was 2.5-times lower (p < 0.01) than average tree density of Group 3 parklands. Group 1 parklands benefitted from seven-fold higher (p < 0.01) application of inorganic fertilisers than in Groups 2 and 3 parklands. As a result, average maize grain yield in Groups 2 and 3 parklands was 26 % lower than that of Group 1 parklands. The amount of herbicide used in Group 2 parklands was fivetimes greater than in Group 1 parklands. Our study strongly suggests that interventions to improve shea-maize parklands in northern Benin should be tailored to location specific characteristics.

Keywords: Farm management practices, shea maize parklands, shea tree density

Contact Address: Geronime Marlene Houeto, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Ouagadougou, Burkina Faso, e-mail: hgeronime@gmail.com

Comparison of the amount of carbon sequestered in different land use in the Amazon highland

Karolína Chalupová¹, Lenka Ehrenbergerová¹, Jorge Mattos Olavarría², Jesus Hernández Castán²

¹*Mendel University in Brno, Dept. of Forest Botany, Dendrology and Geobiocenology, Czech Republic*

²GITEC-IGIP GmbH, Dept. Climate and Natural Resources, Germany

The Andean tropical mountain forest includes many types of ecosystems, which, to some extent, are capable of carbon sequestration. With ongoing climate change, it is very important to understand the global carbon cycle better. This study aims to assess carbon sequestered in different land use (coffee agroforestry systems, tropical cloud forests, and pastures) in the Peruvian Amazon highland. From coffee agroforestry systems (CAS), three smallholders with *Coffea arabica* and different shading trees (Pinus tecunumannii, P. oocarpa, P. patula, and Inga spp.), with average density of 251 ± 157 trees ha⁻¹, were selected. These agroforestry plantations were compared to secondary grown sparce forest stands, which represent the regional vegetation of the studied area, with average density of 220 ± 76 trees ha⁻¹. Pastures were composed of Setaria spp. and Cynodon nlemfuensis. In total, 77 study plots on 8 transects were compared. Location, total tree height and diameter at breast height $(1,3 \text{ m}; \text{DBH} \ge 5 \text{ cm})$ were recorded. To estimate aboveground biomass and carbon, allometric equations were used. Root biomass was estimated with an equation by Cairns et al. (1997). The results varied across different land use types. In pastures, the total carbon amount was estimated on 12,71 Mg ha⁻¹. The evaluation of soil carbon stocks (within the depth of 30 cm) was determined based on soil analysis using a Soli-TOC device (Elementar, Langenselbold Germany), where carbon (TOC) was determined by thermal differentiation (DIN19539 method). Soil carbon stocks were highest in forest stands in the upper soil layers. At lower depths (20–30 cm) the difference between the studied ecosystems was no longer registered.

Keywords: Agroforestry, carbon, carbon sequestration, climate change, coffee, land use, Peru

Contact Address: Karolína Chalupová, Mendel University in Brno, Dept. of Forest Botany, Dendrology and Geobiocenology, Zemědělská 3, 613 00 Brno, Czech Republic, e-mail: xchalup4@mendelu.cz

How to foster transformative solutions in agriculture through the WEF-biodiversity nexus?

Diana Cristina Moreno Vargas¹, Leidy Tatiana Silva Ruíz², Jeimy Andrea García García², Jorge Armando Amador², Alexander Rincón-Ruíz³, Olga Lucía Hernández-Manrique⁴

¹National University of Colombia, Transnational Centre for Just Transitions in Energy, Climate and Sustainability (TRAJECTS), Colombia

²Alexander von Humboldt Biological Resources Research Institute, Colombia

³National University of Colombia, Economics Schools, Colombia

⁴Basque Centre for Climate Change - BC3, Adaptation Lab, Spain

The expanded Water-Energy-Food-Biodiversity nexus emerges as a fundamental research category to explore the intersection between agriculture and environmental conservation and understand food provision landscape transformation due to cultural constructs. This systemic approach recognises that comprehending varying degrees of sustainability scenarios requires holistically integrating the essential elements of water-energy-food-biodiversity, acknowledging their interconnectedness and influence over the changes generated in Socioecological Systems. Participatory research was conducted among local stakeholders during the field phase in the Siecha River micro-watershed in Guasca, Colombia, aimed at collaboratively defining key elements and variables in agricultural transformation. Through stakeholder workshops and field visits, the interrelationships, and characteristics of sustainability transitions within the WEF-Biodiversity nexus were explored in the following central dimensions of analysis: (1) Utilisation of the natural environment, (2) Well-being and governance, (3) Benefits from the natural environment, and (4) Biodiversity conservation and management. Primary information gathering tools such as "The Little House" and "Relationships between the Nexus elements" were employed for this purpose. Findings suggested that the rapid shift towards agro-industrial activities in natural environments has disrupted the provision of ecosystem services and weakened the inhabitants' connection with nature. Despite facing socio-cultural and economic challenges that impact local identity and labour relations, the inhabitants still value the health and well-being benefits nature provides. They recognise the importance of cultural services, such as education and traditional ecological knowledge, which foster the territory's willingness to embrace sustainability transitions. Pollination is particularly valued as a crucial ecosystem service.

Contact Address: Diana Cristina Moreno Vargas, National University of Colombia, Transnational Centre for Just Transitions in Energy, Climate and Sustainability (TRA-JECTS), Calle 44 # 45 – 67. Unidad Camilo Torres Bloque b2, Bogotá, Colombia, e-mail: dcmorenov@unal.edu.co

Consequently, sustainable agricultural practices are being promoted, including the conservation of natural remnants, restoration of water sources, and the implementation of silvopastoral systems with small ruminants to control invasive plants. Considering the intricate challenge of establishing the elements and interrelationships in the WEF nexus, the need to address a holistic view of the study of sustainability agricultural transitions that recognises the inherent interconnectedness between human-nature relationships is evident. This approach transcends merely technical and economic considerations, also exploring the dynamics and social tissue that connect these elements, emphasising how relevant these transitions are for the well-being of the territories.

Keywords: Ecosystem services provision, environmental conservation, sustainable agriculture practices, transformative solutions, water-food-energy nexus

Role of folk nomenclature in understanding and managing plant diversity

NISHANTH GURAV¹, ZBYNEK POLESNY¹, MOHAMED ABDUL KAREEM² ¹Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Czech Republic ²The University of Trans-Disciplinary Health Sciences and Technology, Centre for Conservation of Natural Resources (CCNR), India

Folk nomenclature is how cultures name, identify and classify living organisms. Previous studies have indicated that folk classification will eventually prove helpful in better understanding of local biodiversity and primitive man's understanding of the natural Universe. Indigenous people name and classify living organisms based on their local history, experience, ethnoecological knowledge, and specific habitats connected with culturally important species. The folk plant names used by people of Gond tribe in the Bastar region of central India provide vital information on plant morphological traits and plant-environment interactions. The Gonds' indigenous language has extensive terminologies related to plants. This specific biocultural diversity needs to be addressed as the indigenous knowledge is disintegrating and could be useful for future biodiversity management. Therefore, the study aims to document and analyse the local plant nomenclature in the context of biodiversity management. The study was part of a Ph.D. thesis and conducted over a span of 4 months in selected Gond villages in three districts across the Bastar region of Chhattisgarh. Important stakeholders in the field such as village heads, Biodiversity Management Committees (BMC), District Forest Officers and plant knowledge holders were identified during the initial phase. The study sites were randomly sampled villages/hamlets. The data were collected through interviewing informants selected by snowball and purposive sampling. Followed by identification, data was collected using focus group discussions to enlist local names, household interviews for meanings of names and 'walk in the woods' method to document identification strategies. The herbarium specimens of plant species investigated were collected, identified taxonomically and deposited at the Herbarium and Raw drug repository at Trans-disciplinary University, Bangalore. 210 plant species belonging to 90 families were documented including herbs, shrubs, trees, climbers and tubers. Analysis of their folk names revealed that the local names describe vital information on species habitat, morphology, phenology, uses and taste characteristics. The results also showed the studied community has a specific system of classification and naming of plants. Data acquired could be useful for local stakeholders working on plant management and biodiversity conservation.

Keywords: Agrobiodiversity, biodiversity conservation, ethnobotany

Contact Address: Nishanth Gurav, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Na Rybarce 105/9, 160 000 Prague, Czech Republic, e-mail: gurav@ftz.czu.cz

Decomposition rate and other indicators for ecosystem services evaluation in African agroecosystems

Helena Cristina Serrano, Cristina Branquinho

Fac. of Sciences of the University of Lisbon, Center for Ecology, Evolution and Environmental Changes (cE3c) & Global Change and Sustainability Institute (CHANGE), Portugal

In agroecosystems humans' actions interfere with the natural biogeochemical cycles, but the different management options will render different impacts on the ecosystem services delivery in general and on the ones of nutrient and carbon cycle/decomposition in particular.

Organic matter decomposition is essential for restoring soil fertility by the turnover between organic and mineral forms, that is achieved by physical, chemical, and biological action, at several biodiversity levels, that convert back the organic molecules into plant-assimilable nutrients. The plant decomposition rate depends on the quality and quantity of the litter, the local environment (soil and climate) and on the biodiversity and activity of the decomposition microorganisms present. While decomposition is a regulatory/maintenance service, other types of ecosystem services can be evaluated also in agroecosystems, using other indicators, to estimate their sustainability. In fact, although provision services are more used to evaluate ecosystem services in agriculture, for a complete picture on sustainability, regulatory/maintenance and cultural services should be evaluated, and their tradeoffs considered.

We will give examples of the application of a standardised method for decomposition assessment (teabag method) and provide other indicators of ecosystem services in African agroecosystems.

Results show that in just a few months it is possible to differentiate the decomposition rate in soil of different cultures (e.g., cereals, maize, agroecological pollinator strips, agroforestry) based on biodiversity and microclimate. In more natural systems, at local scale, biodiversity drives decomposition, but in agroecosystems the human inputs modify those processes, either increasing their rate or decreasing it, and should be interpreted with care and appropriate controls.

Keywords: Agroecosystems, biodiversity, decomposition, ecosystem services, sustainability

Contact Address: Helena Cristina Serrano, Fac. of Sciences of the University of Lisbon, Center for Ecology, Evolution and Environmental Changes (cE3c) & Global Change and Sustainability Institute (CHANGE), Campus FCUL C2.5.37, Campo Grande, 1749-016 Lisboa, Portugal, e-mail: hcserrano@ciencias.ulisboa.pt

The impact of soil management, agroecological zone, and season on ground-dwelling insect diversity in Tunisian olive groves

Amel Ben Hamouda 1, Olfa Boussadia 1, Pierre Ellssel 2, Marius Hobart 3, Stéphanie Saussure 4

¹Olive Institute (IO), Tunisia

²BOKU University, Dept. of Crop Sciences, Austria

³Leibniz Inst. for Agricultural Engineering and Bioeconomy (ATB), Agromechatronics, Germany

⁴Natural Resources Institute Finland (LUKE), Finland

In conventional farming system, Tunisian olive groves are usually managed intensively to optimise yields, without considering possible negative impacts on biodiversity. Agroecology for sustainable olive growing recommends several practices to counter this oversight, such as no tillage or cover crops. In this study, insect diversity was assessed in two olive groves, each located in a different agroecological zones (AEZ): Toukaber in Beja Governorate, and Jammel in Monastir Governorate. Three soil management practices were tested: Tillage, No tillage, and Faba bean cover crop, with three replicates in Toukaber olive grove and five in Jammel. Sampling was carried out in 2022 using eight pitfall traps per replicate at two periods: olive flowering and fruit ripening. Our study showed that the number of insect orders was higher in Toukaber than in Jammel with 15 vs. 12 orders during flowering and 15 vs. 11 orders during fruit ripening, respectively. In Jammel, the most abundant order was Collembola (43.65%), found during olive flowering in the practice of Faba bean cover crop. Collembola may, therefore, be positively affected by the companion crop. During fruit ripening, Hymenopteran insects were the most abundant in no tillage (66.66%) due to the dominant ants' activity. In Toukaber, Hemiptera was the most abundant during flowering in the tillage practice (28.09%) and Hymenoptera was the most abundant in Faba bean cover crop (68.02%). The latter practice seemed to promote wasps and pollinating insects. Based on Shannon index values, insect diversity was higher in No tillage during flowering and in Faba bean cover crop during fruit ripening. In addition, tillage seemed to have a negative effect on insect diversity in both seasons for the two AEZs. It can be concluded that the transition to agroecology, by reducing tillage and introducing cover crop, can contribute to the enhancement of insect diversity in olive groves.

Keywords: Agroecosystem, biodiversity, intercropping, orchard

Contact Address: Amel Ben Hamouda, Olive Institute (IO), Sousse, Tunisia, e-mail: benhamoudaayedamel@gmail.com

Biocultural diversity in agroforestry systems in Togo and Benin

Lena Grieger

Goethe University Frankfurt, Institute of Physical Geography & Center for Interdisciplinary African Studies, Germany

For more than four decades, agroforestry has been object of research in several disciplines highly praised as innovative, although the practice of integrating forestry into agriculture and animal husbandry presumably stretches back to the beginning of agriculture itself. Both in Togo and Benin, traditional agroforestry plays a significant role in food security and is of great socio-cultural and medicinal value. At the same time, 'modern' agroforestry practices are gaining considerable interest as strategies for climate change adaptation and mitigation as well as carbon sequestration, reforestation, income stabilisation, yield improvement, agrobiodiversity and soil conservation. From a global point of view, agroforestry practices are considered to offer multiplewin solutions to address local and global challenges. In this context, local knowledge remains often overlooked or seen as a counterpart to scientific knowledge rather than an equal part of identifying innovations, solutions, and ways forward.

In Togo and Benin, there is still a lack of studies dealing with the heterogeneity of small-scale agroforestry farmers, their diversity, flexibility and resilience, traditional and 'modern' practices, local environmental conditions, and capacity of adaptation to and mitigation of climate change. It is at this point, where the study aims explore biocultural diversity in agroforestry systems in the two neighbouring West African countries. Within this framework, the relationship between biodiversity and human diversity as well as distinctive knowledge and skills are taken into account countering broad generalisations on Africa. The overarching objectives of this study are to take inventory of traditional and modern agroforestry practices in Togo and Benin and to map existing agroforestry systems within each agroecological zone of both countries based on case studies covering different climatic and ground conditions. To capture the complexity of the local agroforestry systems, a mixed-method approach is applied including remote sensing, exploratory interviews, and data base research. Mapping and understanding the biocultural diversity of agroforestry systems in Togo and Benin brings the assessment of the actual and potential contribution to climate change adaptation and mitigation as well as biodiversity conservation forward and helps to reevaluate existing agroecological knowledge.

Keywords: Agroforestry, biocultural diversity, climate change adaptation, small-scale agriculture, social-ecological systems, West Africa

Contact Address: Lena Grieger, Goethe University Frankfurt, Institute of Physical Geography & Center for Interdisciplinary African Studies, Altenhöferallee 1, 60438 Frankfurt, Germany, e-mail: l.grieger@em.uni-frankfurt.de

Navigating the drought's grip: Cocoa yield dynamics in agroforestry systems in Ghana and Togo

Afi Amen Christèle Attiogbe 1 , Emmanuel Quansah 2 , Udo Nehren 3 , Enoch Bessah 4 , Agodzo Sampson 4

¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), College of Engineering, Ghana

²*Kwame Nkrumah University of Science and Technology (KNUST), Dept. of Meteorology and Climate Science, Ghana*

³TH Köln - University of Applied Sciences, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Germany

⁴*Kwame Nkrumah University of Sciences and Technology (KNUST), Dept. of Agricultural and Biosystems Engineering, Ghana*

Cocoa is an important agricultural commodity and holds significant economic and cultural value for the livelihoods of millions of households around the world, especially in West Africa, which accounts for around 70 % of the global production. Production is influenced by both on-farm management and agronomic factors (nutrients, pests, shade coverage, and diseases), as well as environmental factors including climate, soil conditions, and water availability. In the green landscapes of Ghana and Togo, Drought is having a devastating effect on cocoa yields, challenging the vitality and sustainability of cocoa production. This work focuses on assessing the effect of drought on cocoa yields in the bordering region of Ghana and Togo over forty years (1981–2020). We extracted cocoa yield data from the FAO, UTCC, and COCOBOD databases, while climate variables, including minimum temperature, maximum temperature, and rainfall, were obtained from meteorological data sources. They were used to explain the variation observed in the data. We used the Standardized Precipitation Evapotranspiration Index on a 12-month scale (SPEI12) as a proxy for agricultural drought quantification. We further used an autoregressive distributed lag (ARDL) to account for the dynamic impact of drought on cocoa yields. The study revealed only a short-term relationship between climate variables and cocoa yield. The study showed that drought reduced cocoa yield by 0.6% and 0.08% in Togo and Ghana respectively. While rainfall and minimum temperature have a positive impact on the cocoa yield, the maximum temperature has a negative effect and positive effects in Togo, and Ghana respectively. The effect climatic variables and drought index were not statistically significant. Only the first lag (the previous year value) of the cocoa yield was significantly affecting the actual cocoa yield.

Contact Address: Afi Amen Christèle Attiogbe, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), College of Engineering, PMB KNUST, Kumasi, Ghana, e-mail: attiogbe.a@edu.wascal.org

This could relate to the impact of the previous years' agronomic practices, such as pruning and fertiliser application, on the current year, since cocoa is a perennial species and exhibits interannual behaviour. Notwithstanding the non-statistical significance of climate variables, the study suggests developing appropriate drought risk reduction strategies in cocoa systems to avoid harsh and undesirable consequences of drought disasters.

Keywords: Cacao, climate change, Ghana, Togo, yield gap

Scaling complex agroforestry: Constrained by labour demand?

Jonas Steinfeld¹, Murilo Almeida-Furtado¹, Luiz Octavio Ramos Filho², Rogier Schulte¹

¹Wageningen University & Research, The Netherlands ²EMBRAPA, Environment, Brazil

More complex agricultural systems such as agroforestry can increase much needed soil-based ecosystem services, but it is often postulated that agroforestry requires higher labour demand. As farmers are experiencing increasing labour shortages, it is important to assess whether agroforestry complexity indeed increases labour demand. We used ten case-study systems that represent a complexity gradient in south-eastern Brazil to assess total labour demand, as well as labour inputs for fertilisation, weeding, pest control, crop management, biomass management and harvesting. We also compared labour requirements to reference monocultures and surveyed farmers on challenges regarding the scaling of their agroforestry systems. Our results confirm that in general, higher agroforestry complexity indeed correlates to higher labour demands and to higher ecosystem service provision. However, our results also show more intricate relationships: the trade-off between complexity and labour requirements was particularly evident in successional agroforestry systems, which had highest structural complexity levels; in less complex multistrata agroforestry systems, which are still more complex than monocultures, total labour demand was found to be lower than in reference monocultures. In successional systems, substantially more time was invested on *in situ* biomass management and less time was spent on pest control and weeding than in monocultural systems. Furthermore, farmers of more complex successional agroforestry perceived challenges at field and farm scale, such as access to adapted machinery and pruning at height, as more difficult than less complex multistrata agroforestry farmers. Both groups of farmers perceived challenges at regional to national scale as particularly severe, such as access to subsidies and competing with conventional products in the market. These findings suggest that increasing complexity in itself does not by definition lead to increased labour demands (e.g. multistrata), but rather that it is the purposeful maximisation of ecosystem service delivery that requires labour intensive management (e.g. pruning & mulching).

Keywords: Ecosystem services, labour demand, successional agroforestry

Contact Address: Jonas Steinfeld, Wageningen University & Research, Farming Systems Ecology, Droevendaalsesteeg 1, 6708 PB Wageningen, The Netherlands, e-mail: jonas.steinfeld@wur.nl

Soil restoration in rubber and cocoa plantations in Côte d'Ivoire

Abenan N'Guettia Léontine Adahé¹, Ebagnerin Jérôme Tondoh², Kouadio Julien N'Dri², N'Gouan Emmanuel Joël Abrou¹, Constant Yves Adou Yao³

¹Félix Houphouët-Boigny University, Biosciences, Côte d'Ivoire

²Nangui Abrogoua University, Sciences of Nature, Côte d'Ivoire

³Félix Houphouët-Boigny University, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire

Soil is an essential natural resource for agricultural production. In Côte d'Ivoire, extensive farming has reduced cultivable soil resources. In order to restore these soils, several initiatives have been proposed, including agroforestry. With this agricultural practice in mind, a study was carried out to assess the physico-chemical quality of soils in rubber and cocoa plantations in Central-western and Southern Côte d'Ivoire. Thus, the diversity of trees associated with the main crops (rubber and cocoa) was assessed in 7, 15 and 30 year-old plantations. Soil samples were used to determine bulk density and weight-average diameter. Finally, chemical elements such as carbon, nitrogen and exchangeable bases were measured in composite soil samples. The results revealed that rubber plantations are rich in 5 tree species divided into 5 genera and 4 families. Rubber plantations aged 15 years have the highest number of trees, with 5 stems.ha⁻¹, corresponding to a basal area of 0.79 m².ha⁻¹. Cocoa plantations contain 38 tree species divided into 33 genera and 13 families, including 4 species with special status. Old cocoa plantations (30 year-old) are the most densely wooded, with 56.84 stems.ha⁻¹, while basal area is highest in 15-year-old cocoa plantations, with 7.04 m^2 .ha⁻¹. In terms of soil physico-chemical quality, cocoa farming has contributed to the conservation of physical soil quality. DMP does not vary between the different habitats. In contrast, rubber cultivation has contributed to the restoration of physical soil quality as the age of the rubber plantation increases. The vast root system of rubber trees could justify this result. DMP is higher in cocoa plantations, with lower bulk densities. Chemical element contents are relatively higher in cocoa plantations than in rubber plantations. Principal component analysis revealed that exchangeable base contents (Mg^{2+}, K^+) increase with the age of the rubber plantation, while Na⁺ decreases. Considering cocoa plantations, carbon and nitrogen contents are higher in 15-year-old plantations, which host the largest-diameter trees. TThe adoption of agroforestry in all cropping systems is a beneficial option for soil restoration.

Keywords: Agroforestry, cocoa plantation, land degradation, rubber plantation, soil quality

Contact Address: Abenan N'Guettia Léontine Adahé, Félix Houphouët-Boigny University, Biosciences, Abidjan, Côte d'Ivoire, e-mail: leontineadahe@gmail.com

Soil and plant nutrition management

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Enhancing crop productivity through fertiliser applications to neglected and under-utilised crops in sub-Saharan African countries: A meta-analysis

Rodolphe Aziz¹, Margherita Rizzu¹, Antonio Pulina¹, Roula Khadra², Giovanna Seddaiu¹

¹UNISS - University of Sassari, Agricultural Science - Desertification Research Center, Italy

²CIHEAM BARI - Mediterranean Agronomic Institute of Bari, Sustainable Water & Land Managament in Agricultural Ecosystems, Italy

Land degradation, soil nutrient depletion and loss of biodiversity have intensified over the years with sub-Saharan Africa. In response, neglected and underutilised crop species (NUS) are garnering attention within African farming systems due to their adaptability and valuable nutritional content. To assess their potential impact, we conducted a meta-analysis focusing on the effects of both organic and inorganic fertiliser applications across several NUS crops, including groundnut, millet, teff, lablab, fonio and anchote.

Our study involved fourteen selected research papers, from an initial pool of 106 publications. The selection process followed a systematic approach, defining inclusion criteria and outlining rigorous methods for literature search, data extraction, metaanalysis, and synthesis.

A three-level random effects model was applied using the metafor package in R. The data were categorized into organic (OF), inorganic (IF), and combination treatments (OF-IF). Forest plots were generated for all the Treatments vs Control and OF, and OF-IF vs IF, in both cases classified by two different moderators. i.e. crop and climate class. Linear models (lm) were fit to assess the significance of the relationships between total nitrogen (Tot N) and Log Response Ratio (LRR) across different crops, fertilisation treatments and climate class on R environment.

When comparing treatments to control, Millet under OF-IF showed a significant yield increase of 77%. Additionally, Teff under IF also demonstrated a notable yield increase of 74%, Under semi-humid climates, the OF-IF and IF showed a yield increase of 101% and 77% respectively. On the other hand, when comparing treatments to inorganic, Teff exhibited 109% and 119% of yield improvements under both OF-IF and OF respectively. In Humid climates, the OF-IF resulted in 118% yield increase.

Full OF showed a strong positive relationship between yield increase and Tot N, with R^2 of 0.74 and P value of 0.013. Similarly, Teff under OF exhibited a strong relationship between yield increase and Tot N, with R^2 of 0.67 and P value of 0.025, indicating significant impacts of Tot N on yield. These findings underscore the importance of integrating organic and inorganic fertilisation to enhance NUS productivity, offering valuable insights for the sustainability of African cropping systems.

Keywords: Crop yield, fertilisation systems, multilevel analysis, NUS

Contact Address: Rodolphe Aziz, UNISS - University of Sassari, Agricultural Science - Desertification Research Center, Viale Italia 39A, 07100 Sassari, Italy, e-mail: raziz@uniss.it

Maize response to fertiliser microdosing in agroforestry parklands in the Savannah region of Ghana

Deogratias Kofi Agbotui¹, Geronime Marlene Houeto¹, Amisu Mohammed², Vincent Avornyo², Jesse B. Naab³, Andreas Buerkert¹

¹University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Germany

²University for Development Studies, Dept. of Soil Science, Ghana

³West African Science Service Center for Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

Maize (Zea mays L.) is the most important cereal crop in Sub Saharan Africa. Hence, soil fertility management through the application of inorganic fertiliser is critical for sustainable maize production. During the last two decades fertiliser microdosing has been promoted throughout the region as there is ample evidence that it increases maize yield. However, most of these results were obtained from maize monocultures. This study therefore aimed to assess the effect of microdosing on maize yield in Vitellaria paradoxa C.F. Gaertn. parklands in the Savannah Region of Ghana. To this end four isolated V. paradoxa trees were selected in farmer fields whereby each area of tree influence was delineated into canopy area (Zone A), 3 m away from canopy (Zone B), 10 m away from canopy (Zone C), and 20 m away from canopy (Zone D). In each zone, three fertiliser application treatments were implemented on maize. These were (i) farmers' practice without fertiliser application (FP), (ii) microdosing (MD) which involves placing 1.5 g of NPK 15–15-15 into the planting hole together with the seeds $(14 \text{ kg N ha}^{-1}, 6 \text{ kg P ha}^{-1}, 12 \text{ kg K ha}^{-1})$, and (iii) national recommended (NPK) application NPK rate (30 kg N ha⁻¹, 13 kg P ha⁻¹, 25 kg K ha⁻¹) applied at the time of planting and urea $(30 \text{ kg N ha}^{-1})$ applied 6 weeks after planting. For grain yield there was a significant interaction between Zone and fertiliser application whereby grain yield of NPK at Zone D was 2.5-times higher (p = 0.03) than grain yield of FP in Zone A. Average stover yield of NPK and MD was 31 % lower (p < 0.01) than stover yield of FP. Fertiliser use efficiency in MD plots were 44 % higher (p < 0.05) than in NPK plots. Although soil electrical conductivity (EC) and organic carbon (SOC) in Zone A were 28 % and 16 % higher than the averages of Zones B, C, and D, these differences were not statistically significant. We conclude that in agroforestry parklands, maize fertilised with MD can produce yields comparable to the much higher recommended application rate of broadcast fertiliser.

Keywords: Agronomic efficiency, fertiliser application, soil fertility, sustainable agriculture, tree crop interactions

Contact Address: Deogratias Kofi Agbotui, University of Kassel, Organic Plant Production and Agroecosyst. Res. in the Tropics and Subtropics (OPATS), Witzenhausen, Germany, e-mail: deogratiasagbotui@yahoo.com

Preliminary investigation into paddy soil properties and rice growth after humic acid and gypsum applications

Hartina^{1,2}, Phrueksa Lawongsa^{2,1}, Tidarat Monkham³, Patma Vityakon^{1,2}, Tanabhat-Sakorn Sukitprapanon^{1,2}

¹*Khon Kaen University, Dept. of Soil Science and Environment, Thailand* ²*Khon Kaen University, Soil Organic Matter Management Research Group, Thailand* ³*Khon Kaen University, Dept. of Agronomy, Thailand*

Applying soil amendment can improve soil properties and plant growth in problematic soils in tropical regions. However, knowledge of the combined application effects of humic acid (HA) and flue gas desulfurization gypsum (FGD gypsum) on soil properties and plant growth in tropical regions is still limited. The objectives of this study were to preliminary investigate the effects of HA and FGD gypsum application on some soil properties and rice growth in tropical paddy soil which was classified to be Aeric Kandiaquult (Ultisol). The experiment was conducted using pot experiments and was arranged in a completely randomized design with four treatments and three replications. Four treatments consisted of (1) chemical fertiliser application based on farmer practice (CF), (2) CF and HA, (3) CF and FGD gypsum based on gypsum requirement, and (4) CF with combined application of HA and FGD gypsum. The HA and FGD gypsum were applied at 975 and 636 kg ha⁻¹, respectively. The preliminary result revealed that the application of HA not only increased soil pH (1:5), total organic carbon (TOC), total N, exchangeable K, available P, and cation exchange capacity (CEC) but also increased tiller numbers. The soil incorporated by FGD gypsum contained high concentrations of soil exchangeable Ca and S, but it provided lower tiller numbers. The co-applications of HA and FGD gypsum enhanced soil properties including TOC, total N, CEC, and exchangeable K, but it did not improve tiller numbers. Therefore, this preliminary study proposed that applying CF and HA is a suitable approach to improve soil quality and rice growth in the paddy soil.

Keywords: FGD gypsum, humic acid, rice cultivation, Thailand, tropical paddy soil

Contact Address: Hartina, Khon Kaen University, Dept. of Soil Science and Environment, 123 mittraphap road tambon sila amphoe mueang khon kaen, 40002 Khon kaen, Thailand, e-mail: hartina.h@kkumail.com

Regenerative agriculture practices improve soil health in phosphorus deficient soils in western Kenya

PETER BOLO¹, MONICAH MUCHERU-MUNA², MICHAEL KINYUA¹, JOB KIHARA¹ ¹The Alliance of Bioversity International & CIAT, Kenya ²Kenyatta University, Dept. of Environmental Sciences and Education, Kenya

Regenerative agriculture practices are key in promoting soil health, consequently enhancing soil and crop productivity. Assessment of how different regenerative agriculture practices influence key soil health indicators is imperative in broadening our understanding on soil health and quality; and informing the potential for policy advocacy. We assessed the influences of select regenerative agriculture practices (in an 18-year long-term trial) in western Kenya on four key soil health indices namely; i) Nutrient and soil organic carbon (SOC) availability; ii) Activities of 4 extracellular enzymes involved in nutrient cycling, comprising alkaline phosphatase (ALP), acid phosphatase (ACP), beta glucosidase (GLU) and beta-glucosaminidase (NAG), responsible for phosphorus (P), carbon (C) and nitrogen (N) cycling, respectively; iii) Enzyme stoichiometry ratios; and iv) Soil nutrient-enzyme activity relationships. This study was conducted in phosphorus deficient soils in Western Kenya; and was analysed using high-throughput calorimetry measurements. Results showed that regenerative agriculture practices integrating organic inputs (farmyard manure) increased the soil nutrient and SOC availability; elevated activities of the 4 extracellular enzymes involved in C, N and P cycling in the range of 22 % to 144%; enhanced the enzyme stoichiometry ratios and soil nutrient-enzyme activity relationships. Both enzymatic C:N and N:P ratios were significantly enhanced under regenerative practices involving application of farmyard manure. Sole addition of P fertiliser significantly reduced enzymatic C:N ratios whereas enzymatic C:P and N:P ratios were lowest under no input systems. Key extracellular enzyme activities, their stichometry ratios, vector angles and lengths significantly correlated with different parameters involving soil pH, SOC, soil N, ACP, ALP, soil N:P and soil C:P. These results broaden our understanding of the potential soil health benefits associated with sustainable agroecological regenerative practices, calling for more research for scaling and policy advocacy.

Keywords: Agroecological, enzyme activities, enzyme stoichiometry ratios, nutrient cycling, regenerative agriculture, soil health

Contact Address: Peter Bolo, The Alliance of Bioversity International & CIAT, PO Box 25-40611 Nyilima, Kisumu, Kenya, e-mail: p.bolo@cgiar.org

Local soil amendments enhance soil organic carbon quantity and quality in Indonesian post-tin mining soil

Orracha Sae-Tun^{1,3}, Rizki Maftukhah², Ngadisih², Murtiningrum², Gernot Bodner³, Rebecca Hood-Nowotny¹, Axel Mentler¹, Katharina Keiblinger¹

¹BOKU University, Inst. of Soil Research, Dept. of Forest and Soil Sciences, Austria ²Universitas Gadjah Mada, Dept. of Agricultural and Biosystem Engineering, Indonesia ³BOKU University, Inst. of Agronomy, Dept. of Crop Sciences, Austria

Using locally available soil amendments is considered as an effective and affordable strategy to reclaim highly degraded soil, such as in post mining areas. This is especially crucial in tropical regions where soil erosion and decomposition rates are particularly high. Increase in soil organic carbon (SOC) serves as a key indicator of soil health and, consequently, soil productivity improvement. Thus, the study aimed to demonstrate the quantitative and qualitative response of SOC accumulated in a post-tin mining soil in Indonesia during the first four years of reclamation, utilising local soil amendments. Soil samples (0–20 cm) were collected from an experimental plot prior to treatment and then annually after applying dolomite, compost, and charcoal, as well as control (without any amendments). SOC stocks were assessed from the collected samples. Its chemical composition was determined by Attenuated Total Reflectance-Fourier Transform Infrared (ATR-FTIR) spectroscopic technique. The results revealed that the soil amendments used significantly influenced SOC stocks and altered its chemical composition. Compost and charcoal increased SOC stocks by ≥ 40 Mg ha⁻¹ compared to control during the study period. They accelerated SOC gain within the first two years, whereas it required four years to attain SOC acquisition in control. SOC under compost and control shared similar chemical composition with broad variation throughout the study period. The chemical composition of SOC in dolomite amended soil was distinct from the others, and this was notably enhanced by aliphatic hydrocarbons. In contrast, chemical composition of SOC under charcoal exhibited variation over time, highlighting its richness in C-N of amide III in the third year. This indicated a benefit of charcoal for SOC accumulation through absorption of organic substances released by e.g., plant roots. Stronger correlations between SOC chemical composition and both soil pH and EC than its correlation with the amount of SOC implied an indirect effect of soil amendments on controlling SOC quality. Therefore, using compost and charcoal is a potential strategy to improve SOC stock in the studied soil despite differences in their chemical composition.

Keywords: Carbon stock, chemical composition, degraded soil, soil reclamation, tropical soil

Contact Address: Orracha Sae-Tun, BOKU University, Inst. of Soil Research, Dept. of Forest and Soil Sciences, Vienna, Austria, e-mail: orracha.sae-tun@boku.ac.at
Phosphorus fertiliser management for high yields in groundnut-maize rotation system in Ebonyi state Nigeria

Jemrose Chinemerem Ehibe¹, Prince Onyedikachi¹, Theresa Onuekwusi²

¹*Michael Okpara University of Agriculture Umudike (MOUAU), Dept. of Agronomy, Nigeria*

²*Michael Okpara University of Agriculture Umudike (MOUAU), Dept. of Soil Science and Meteorology, Nigeria*

The excessive use of phosphorus (P) fertiliser in crop production can result in a continuous accumulation of soil P, leading to the potential for P leaching from the agricultural ecosystem. However, the effects of balanced P management on soil P availability and crop P absorption remain unknown for groundnut-maize rotation in Ebonyi state Nigeria. To address this gap, a twoseason (2018/2019 and 2019/2020) field experiment was conducted on-farm in Ohozara, Ebonyi state on a demonstration plot belonging to Michael Okpara University of Agriculture Umudike (MOUAU), Nigeria. The experiment involved four different P rates $(30 \text{ kg P ha}^{-1}, 40 \text{ kg P ha}^{-1}, 50 \text{ kg P ha}^{-1}, and$ 60 kg P ha^{-1}) in comparison to a control (0 kg P ha^{-1}) . The primary objective was to assess the impact of a balanced P application strategy on crop yield, P uptake, and soil P accumulation in a groundnut-maize rotation system. The results show that yield and P uptake of groundnut-maize rotation increased with P fertilisation up to $40 \text{ kg P} \text{ ha}^{-1}$, beyond which they stabilised, and the critical threshold is 50 kg P ha⁻¹ for groundnut. Phosphorus fertilisation at 60 kg ha⁻¹ accelerated the downward movement of soil P and stocked it in the deep soil in the form of soil labile P and moderately labile P, which increased the risk of soil P leaching. The annual application of 60 kg ha^{-1} P as 300 kgTSP fertiliser ha⁻¹ increased the total P concentration by 25 %-86 % from deep soil to

topsoil compared to the other treatments. Groundnut-maize rotation in the soils of Ebonyi state used for this study required additional P application to reach the agronomic threshold, set at 20 to 30 kg ha⁻¹ annually by the Ebonyi State Ministry of Agriculture. In conclusion, balanced P fertilisation can reduce soil P surplus and subsoil P stock while maintaining crop yields.

Keywords: Crop yield, fertiliser management, groundnut-maize rotation, phosphorus requirement

Contact Address: Jemrose Chinemerem Ehibe, Michael Okpara University of Agriculture Umudike (MOUAU), Dept. of Agronomy, Umuahia, Nigeria, e-mail: jemroseehibe@gmail.com

Understanding spatial variability of soil physical properties to better inform rainfed soybean and maize cultivation in Southern Africa

EMMANUEL NGONGA¹, YANNIC JANAL², JENNIE BARRON³ ¹International Institute of Tropical Agriculture, LEG4DEV, Zambia ²BOKU University, Inst. of Soil Physics and Rural Water Management, Austria ³Swedish University of Agricultural Sciences, Dept. of Soil and Environment, Sweden

The absence of comprehensive soil data in Sub-Saharan Africa's rainfed agricultural systems presents a significant challenge to sustainable farming practices. This challenge is further compounded by the lack of systematic soil monitoring systems and the dynamic nature of soil conditions influenced by agricultural practices and climate change. These limitations hinder the development of precise tools and strategies for agricultural management in this region. This study addresses these gaps by investigating the spatial variability of soil physical properties in southern Africa and its impact on soybean and maize yield. Specifically, we focus on three distinct agroecological zones in Central, Southern, and Eastern Zambia, where we conducted soil analyses to assess key parameters such as bulk density, texture, organic carbon content, cation exchange capacity, base saturation, and water retention characteristics.

Additionally, we carried out *in situ* water infiltration measurements in selected fields to inform soil pedotransfer functions for estimating saturated hydraulic conductivity, a critical parameter for understanding water movement in soils.

Our preliminary findings reveal significant insights into the soil characteristics of these regions. In Kalomo, consistently sandy loam soils were observed, characterised by a lack of vertical structure. Katete, on the other hand, exhibited a wide range of soil textures, structures, and infiltration rates attributed to its diverse topography and microclimates. The fields sampled in Lusaka, predominantly cultivated by large-scale farmers, displayed higher clay composition but surprisingly showed the highest infiltration rates, likely due to their significantly higher soil organic matter content. The data collected in this study hold immense potential for informing future precision farming strategies in the region. By coupling our understanding of ground-based soil properties with remote sensing techniques to monitor crop productivity, we aim to develop tools and models that can enhance agricultural management practices. This holistic approach will contribute to more sustainable and efficient agricultural systems in sub-Saharan Africa's rainfed regions, ultimately improving food security and livelihoods for farming communities.

Keywords: Africa, maize, pedotransfer, rainfed, soil, soybeans

Contact Address: Emmanuel Ngonga, International Institute of Tropical Agriculture, LEG4DEV, Ngwerere Road Chongwer District, 310142 Lusaka, Zambia, e-mail: emmanuel.ngonga@slu.se

Productivity of soybean-maize-mung bean intercropping in East Java, Indonesia

NAOKO KAWASAKI, TJEERDJAN STOMPH, LOTTE WOITTIEZ, WOPKE VAN DER WERF Wageningen University & Research, Plant Sciences, The Netherlands

Indonesia relies on imported soybeans for over 90% of its consumption. Intercropping with maize has been proposed as a pathway towards increased soybean production. Intercropping of maize and soybean has been reported to improve land use efficiency, but the yield of soybean is negatively impacted by shading from maize. There is little information on what might be optimal plant configurations in different seasons in Indonesia. Hence, we evaluate the productivity of maize-soybean intercropping in Indonesia, while testing different configuration options to mitigate possible shading effects on soybean. Experiments were done across the rainy and dry seasons in 2022 and 2023 at a site near Probolingo, East Java. We compared four configurations:

- 1. a 2M:4S replacement intercrop comprising 2 rows of maize alternating with 4 rows of soybean (replacement intercrop); in this system, we compared two soybean cultivars;
- 2. a 2M:4S replacement intercrop with maize planted at a narrow row distance to increase the space for soybean (replacement intercrop);
- 3. the same 2M:4S maize-soybean configuration as configuration 2, with two mung bean rows planted in the space between soybean and maize (additive intercrop)
- 4. as configuration 2, but with two additional soybean rows, so a 2M:6S additive intercrop.

Grain and biomass yields of each crop species in each treatment were recorded, and the relative land productivity of intercropping was assessed using the land equivalent ratio (LER).

The results showed that the LER ranged between 0.89 and 1.16. Widening the space for soybeans in configuration 2 increased soybean yield without impacting maize yield. Additive intercrops (configurations 3 and 4) had greater LER than replacement intercrops.

Estimates of LER were moderate, diverging from studies reporting high LER (1.61–1.63) in Indonesia, but aligned with research in temperate climates showing limited yield advantage with simultaneous intercropping. The narrow maize row system increased soybean yield but did not adversely affect maize yield.

Keywords: Indonesia, intercropping, maize, soybean

Contact Address: Naoko Kawasaki, Wageningen University & Research, Plant Sciences, Wageningen, The Netherlands, e-mail: naoko.kawasaki@wur.nl

Maximizing carbon sequestration through integration of pigeon pea in smallholder systems across South Asia and Africa

Shem Kuyah¹, Jules Bayala², Kangbeni Dimobe^{3,2}, Karl Hughes², Mattias Jonsson⁴, Tarirai Muoni⁴, Shalander Kumar⁵, A. Sigrun Dahlin⁴, Weldesemayat Sileshi⁶, Ingrid Öborn⁴

¹*Jomo Kenyatta University of Agriculture and Technology (JKUAT), Kenya*

²The Center for International Forestry Research and World Agroforestry, Burkina Faso

³University of Dedougou, Burkina Faso

⁴Swedish University of Agricultural Sciences (SLU), Sweden

⁵International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India

⁶Addis Ababa University, Ethiopia

Sustainable intensification is one of the options recommended for increasing carbon sequestration for the dual purpose of improving crop productivity and mitigating climate change. Yet many questions remain, such as which species give the greatest soil and aboveground carbon benefits. The CGIAR Research Program on Grain Legumes and Dryland Cereals has identified pigeon pea (Cajanus cajan L.) as one of the priority crops capable of transforming underperforming agriculture to become resilient, productive and profitable. Despite the large body of literature on pigeon pea, its contribution to carbon sequestration in agroforestry has not yet been explored. We scanned publications to determine the role of pigeon pea in carbon sequestration in Africa and South Asia. Carbon in post-harvest (aboveground) residues from pigeon pea was 2.21 ± 0.38 Mg ha⁻¹ in Africa and 2.75 ± 0.34 Mg ha⁻¹ in South Asia. Using average root-to-shoot ratio for pigeon pea (0.21), and assuming 47% carbon fraction in dry matter and 65% carbon in rhizodeposition, total carbon potentially available for addition to the soil ranged from 1.21 ± 0.44 Mg ha⁻¹ when residues are removed to 2.98 ± 0.51 Mg ha⁻¹ when residues are retained in Africa, and from 1.50 ± 0.54 Mg ha⁻¹ when residues are removed to 3.70 ± 0.46 Mg ha⁻¹ when residues are retained in South Asia. Absolute soil organic carbon concentration (SOC) on farms with pigeon pea was 1.68±0.19%. The effect of pigeon pea on SOC was positive and significant (lnRR: 0.299, 95 % CI= [0.02, 0.84]). On average, SOC in farming systems with pigeon pea was 35 % higher at the end of experiment relative to values at the start of experiment. High biomass production and SOC increase under pigeon pea shows its potential to build resilience when integrated into current smallholder farms. We discuss the challenges and opportunities for integrating perennial grain legumes in tree-based cropping systems, including recommendation for future research priorities.

Keywords: Aboveground carbon, dryland cereals, rhizodeposition, soil organic carbon, sustainable intensification

Contact Address: Shem Kuyah, Jomo Kenyatta University of Agriculture and Technology (JKUAT), 62000, 00200 Nairobi, Kenya, e-mail: kshem@jkuat.ac.ke

Plant leafy biomass and their manure derivatives effect on *Sorghum bicolor* L. yield in the Sudano-Sahelian zone of Mali

Siriki Fané, Deogratias Kofi Agbotui, Mariko Ingold, Andreas Buerkert

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

The Sudano-Sahelian zone of Mali is a region where Sorghum bicolor L. cultivation plays a significant role for the local economy and food security. In this semi-arid environment, where farmers seldomly apply inorganic fertilisers, sorghum yield is sustained by the application of plant biomass and animal manure. However, because of competing uses, these organic fertilisers are becoming scarce. Therefore, this study aims to determine the agronomic performance of sorghum after a single application at a rate of 8 t ha^{-1} of different locally available plant leafy biomass and their manure derivatives in the 1st cropping year (2022) and without any additional amendment in the 2nd cropping year (2023). The field study was undertaken with *Khaya senegalen*sis, Pterocarpus lucens, Ficus sycomorus and Pennisetum pedicellatum in a randomised complete block design with four replications. Average grain yield in the 1st cropping year was 49 % higher than in the 2nd cropping year. In the 1st cropping year, P. pedicellatum leafy biomass produced the highest grain yield $(1,442 \text{ kg ha}^{-1})$, which was 253 % significantly higher than the lowest grain vield (409 kg ha⁻¹) produced from the unamended control. In the 2nd cropping year, grain yield from *F. sycomorus* plots were 4-times higher (p < 0.05) than from control plots. The average fertiliser use efficiency over both cropping cycles was 35-84% higher in leafy biomass compared with respective manure, except for K. senegalensis. Considering the scarcity of organic manure, P. pedicellatum leafy biomass is a better fertiliser than its respective manure, whereas for the other species farmers might benefit from dual use of leafy biomass as livestock feed and the subsequent use of manure for sustainable farming in the study region.

Keywords: Agroforestry, agronomic efficiency, biomass quality, biomass transfer, smallholder agriculture

Contact Address: Siriki Fané, 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

Manure improvement options for smallholder farmers in the Savannahs of West Africa

Andrews Opoku 1, Mouritala Sikirou 2, Olivier Kashongwe 3, Nouri Garba $\rm Maman^1$

¹*Kwame Nkrumah University of Sciences and Technology (KNUST), Ghana* ²*International Institute for Tropical Agriculture (IITA), DR Congo* ³*Leibniz Institute for Agricultural Engineering and Bioeconomy, e.V. (ATB), Germany*

Efficient management of manure is critical for sustaining crop production and improving efficiency of livestock production in mixed crop-livestock smallholder farms. Manure storage is a hot-spot of greenhouse gas emissions and soil pollution through eutrophication. The effects of oil cakes and manure storage methods on nutrient losses during composting were evaluated at three locations: Nyankpala in Ghana, Zaria in Nigeria and Maradi in Niger. Eight management options were tested at each location by fortifying manure with locally available oil cake and composting it in pits or heaps. Plastic sheets were used to either cover heaps or line pits. The storage of manure in heaps or pits and fortification with oil cake had no effect on N and P losses during composting at all locations. The use of plastic sheets to cover heaps or line pits significantly reduced N losses from 29 – 67 % to 5 – 30 % and P losses from 25 - 37 % to 2 - 20 % at Nyankpala and Zaria but had no effect on nutrient losses at Maradi. Although the fortification of manure with either groundnut cake or cotton seed cake increased the N content of the manure by 45% to 130%, the high cost of these oilcakes precluded their use as compost additives. The low cost of acquiring shea nut cake made it the most suitable compost additive. The findings of the study provide locally available options to reduce nutrient losses from manure with heap and line pits and low cost composting additives to improve the fertiliser value of manure on smallholder farms.

Keywords: Composting, manure storage, nitrogen losses, oil seed cake, plastic sheets

Contact Address: Olivier Kashongwe, Leibniz Institute for Agricultural Engineering and Bioeconomy, e.V. (ATB), Max-Eyth-Allee 100, 14469 Potsdam, Germany, e-mail: okashongwe@atb-potsdam.de

Nitrogen availability as result of interaction between fertiliser and soil properties

Robert Kahle, Hans Jürgen Reents

Technical University of Munich, TUM School of Life Siences, Institute of organic agriculture and plant production systems, Germany

Scientific studies as well as observations and experiences in gardening practice have shown that soils have a highly varied ability to release nutrients, especially nitrogen. Organic fertilisers can exhibit very different rates of nitrogen release at different locations. Understanding nitrogen release from organic fertilisers and its interaction with soil properties is essential for estimating nitrogen mineralisation potential, adapted fertilisation and reducing negative environmental impacts. We conducted incubation and greenhouse experiments with agricultural and horticultural soils to study the impact of clay content and carbon to nitrogen ratios of organic fertilisers on nitrogen mineralisation and plant nitrogen availability. Results showed soil and fertiliser nitrogen mineralisation varying by site, with management history and clay content as significant factors, whereas no soil-fertiliser interaction across sites could be observed. Soil clay content influenced the magnitude and course of nitrogen release, but this was inconsistent across the different farms. Agricultural soils had higher nitrogen mineralisation and plant nitrogen uptake, whereas fertiliser effects were greater in horticultural soils. The higher the carbon to nitrogen ratio of the fertiliser, the lower the nitrogen release, with differences in magnitude and timing as well as location-specific variations. This study suggests that plant-based fertilisers with carbon to nitrogen ratios greater than 10 may not suit short cultivation periods and thus applicability in organic vegetable production. Site-specific management history influences nitrogen mineralisation greater than soil clay content and fertiliser carbon to nitrogen ratio. These findings highlight the importance of the specific investigation of management history for further understanding and improving of fertilisation efficiency.

Keywords: Clay content, CN-ratio, N-mineralisation, soil-fertiliser-interaction

Contact Address: Robert Kahle, Technical University of Munich, TUM School of Life Siences, Institute of organic agriculture and plant production systems, Liesel-Beckmann-Straße 2, 85354 Freising, Germany, e-mail: r.kahle@tum.de

The potential use of diatomaceous earth for improvement of paddy rice production in Thailand

FAPAILIN CHAIWAN, NATCHANON SANTASUP, CHOOCHARD SANTASUP Chiang Mai University, Dept. of Plant and Soil Sciences, Thailand

This experiment was carried out to evaluate the effects of diatomite in combination with chemical fertilisers on the growth and yield of paddy rice, Niaw San-Pah-Thong 1 (Thailand variety). The experimental design was a randomised complete block design (RCBD) with 3 replications and 6 treatments, as follows: (1) control (without diatomite and chemical fertiliser application) (2) diatomite application at the rate of 18.00 kg ha^{-1} ; (3) application of chemical fertiliser at the recommended rate in Thailand $(N:P_2O_5:K_2O =$ $1.14:1.36:0.24 \text{ kg ha}^{-1}$ (4) application of diatomite (18.00 kg ha^{-1}) in combination with chemical fertiliser (5) application of diatomite $(18.00 \text{ kg ha}^{-1})$ in combination with 75% of chemical fertiliser; and (6) application of diatomite (112 kg ha⁻¹) in combination with 50 % of chemical fertiliser. Plant height and plant numbers per tiller were measured at 20, 30, 40, and 50 DAT (days after transplanting). SPAD and primary nutrients (nitrogen, phosphorus, and potassium) in rice leaf were analysed at 60 DAT. At the harvest stage (120 DAT), grain yield, yield components, and primary nutrients in the seed were determined. The results showed that application of diatomite in combination with different rates of chemical fertilisers did not significantly affect rice growth (plant height, plant numbers per tiller), SPAD, primary nutrients in rice leaves, and yield of rice. But when diatomite was used with different amounts of chemical fertilisers, the plants grew taller than treatment 3 (which used chemical fertiliser at the recommended rate). The highest rice yield (156 kg ha⁻¹) was achieved when diatomite was applied in combination with 50% chemical fertilisers (treatment 6). Therefore, we selected the application of diatomite at a rate of 18.00 kg ha⁻¹ as the recommended fertiliser programme for Niaw San-Pah-Tawng 1 cultivation due to the low rate of fertiliser application and the high growth and yield obtained. Moreover, the low amount of fertiliser applied indicated the high efficiency of fertiliser usage and the reduction of chemical fertiliser residues in the soil.

Keywords: Rice, diatomite, chemical fertiliser

Contact Address: Fapailin Chaiwan, Chiang Mai University, Dept. of Plant and Soil Sciences, 239, Huay Kaew Road, Muang District, 50200 Chiang Mai, Thailand, e-mail: fapailin.c@cmu.ac.th

Improving rice production through digital technology: Validating the RiceAdvice decision support tool in Mali

Charles Chigemezu Nwokoro 1 , Samuel Guindo 2 , Sunil Hemdev 2 , Robert Berlin 2 , Johan Six 1

¹*ETH Zürich, Environmental Systems Science, Switzerland*

²Syngenta Foundation for Sustainable Agriculture, AgriServices program, Switzerland

Traditional blanket fertiliser rates and conventional fertiliser management practices among smallholder farmers in Mali have often fallen short of delivering significant yield improvements and economic gains in rice production. However, applying digital technology to provide personalized fertiliser rates and management recommendations holds promise for improving rice yields and economic returns for smallholders. In 2022, 47 non-replicated on-farm trials were carried out in 17 villages in the Sikasso, Soudan-Guinean agroecology of Mali to compare the fertiliser rates and management recommendations of a mobile application, RiceAdvice, with conventional farmer practices in flooded rice cultivation. We find that the use of the RiceAdvice tool led to an average increase in paddy yield by 18% (1.5 t ha⁻¹) and a 17% improvement in nitrogen (N) use-efficiency (10.4 kg paddy N kg⁻¹) compared to conventional farmer practices, without increasing the overall quantity of fertiliser used. However, significant differences were observed in the timing and amount of fertiliser application between RiceAdvice and conventional farmer practices: in RiceAdvice plots, an average of 41 kg N ha⁻¹ as NPK 17:17:17 was applied basal, while conventional practices involved applying on average 38 kg N ha⁻¹ 15 days after transplantation (DAT) of rice. Furthermore, in the RiceAdvice plots, 47 kg and 56 kg N ha⁻¹ were top-dressed as urea at 27 and 43 DAT, respectively, whereas in conventional farmer practice, averages of 91 kg and 22 kg N ha⁻¹ as urea were top-dressed 45 and 60 DAT, respectively. The first and second N top dressing in the RiceAdvice treatment plots represented 31% and 37% of total top-dressed N, respectively. In the farmer practice it represented 81%and 19%, respectively. The second urea top dressing occurred by choice only in 23% of the plots in the farmer practice against 100% in RiceAdvice plots by recommendation. The average benefit-cost ratio of the RiceAdvice technology was higher (2.4 USD USD^{-1}) with government fertiliser subsidy than without (1.3 USD USD^{-1}). We conclude that extending the RiceAdvice decision support tool services could improve rice productivity, N use-efficiency, economic profitability, and livelihoods in Mali without increasing the amount of fertiliser used in rice production.

Keywords: Benefit-cost ratio, decision support tool, digital technology, nitrogen useefficiency, profitability, rice yield, RiceAdvice tool

Contact Address: Charles Chigemezu Nwokoro, ETH Zürich, Environmental Systems Science, Universistatsstrasse 2 lfh2, 8092 Zurich, Switzerland, e-mail: charles.nwokoro@usys.ethz.ch

Effect of seedbed depth on ginger (*Zingiber officinale*) yields in Uganda

Jacob Kaingo¹, George Jjagwe², Costa Gumisiriya², Joad Mugisha Mwesige², Geofrey Candia², Efrance Najjuma², Clovis Kabaseke², Joshua Wesana²

¹Sokoine University of Agriculture, FoCoActive Project, Tanzania

²Mountains of the Moon University, School of Agriculture and Environmental Sciences, Uganda

Ginger (Zingiber officinale) is a popular herbaceous perennial used in spicing food and beverages in Uganda. However, population pressure is constraining available farmland for its cultivation. We hypothesised that enhanced seedbed depth could be a pathway for increasing ginger yields amidst competing land uses. An experiment was undertaken to assess the effect of seedbed depth on ginger yields. The experiment was set up in a Randomised Complete Block Design in three replications with treatments as seedbeds made of pits of depth; 1.8 m, 1.3 m, 0.8 m plus a control (0 metres). Pits were filled with maize cobs and a 30 cm soil+compost layer as planting media. Ginger rhizomes were planted at 25 cm × 25 cm intervals between and within rows with a plant population of 16. Ginger was harvested from each of the plots after 8 months to determine yield. Fresh weight was determined with a weighing balance and sub samples of rhizomes and shoots were oven dried for dry weight determination at 70 oC for 48 hours. Analysis of variance was used to assess the effect of treatments with Tukey's test used for post-hoc analysis. Highest ginger rhizome yield was from seedbeds of 1.3 M depth and lowest was from the Control, with yields of 6.02 t ha⁻¹, and 2.31 t ha⁻¹, respectively. Ginger yields with greatest seedbed depth (1.8 M) were 2.63 t ha⁻¹. Statistically significant differences (p < 0.05) were observed between yields for seedbed with 1.3 M depth compared with seedbeds of 1.8M depth and the Control but not the seedbed with 0.8M depth. Shoot yields followed a similar statistical trend of the order 1.3 M > 0.8 M > 1.8 M > Control with yields of 1.44 tha⁻¹, 1.13 tha⁻¹, 0.69 tha⁻¹, and 0.2 tha⁻¹, respectively. Results suggest an influence of seedbed depth on ginger yields with an optimal depth being 1.3 M. Nonetheless, a multiseason trial will be essential for validation of the results.

Keywords: Ginger yields, land use, seedbed depth, Uganda

Contact Address: Jacob Kaingo, Sokoine University of Agriculture, FoCoActive Project, P.O. Box 3006, Morogoro, Tanzania, e-mail: jacobkaingo@gmail.com

Assessing impact of forest landscape restoration on the erosion of agricultural land in sub-Saharan Africa Mékrou's watershed

Abiolla Robertson Kévin Amoussou^{1,2}, Michel Kabirigi¹, Katharina Löhr¹, Christine Ouinsavi²

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

²University of Parakou-Benin, Laboratory of Forestry Studies and Research (LERF), Benin

Soil erosion stands as one of the foremost challenges confronting agricultural productivity, posing a significant threat to global food security. Numerous studies have explored the potential of Forest Landscape Restoration (FLR) practices to mitigate the adverse effects of soil erosion. However, it's crucial to recognise that the efficacy of these practices may vary across different contexts and environments. Our primary objective is to evaluate the impact of FLR initiatives on reducing soil erosion in agricultural lands within the Head of Mékrou Watershed (TBVM) in Benin. TBVM correspond to a semi-arid area of 361 km². We assessed the potential annual soil loss within the watershed by using the Revised Universal Soil Loss Equation (RUSLE) in combination with geographic information system (GIS) technology and remote sensing data. Rain erosivity (R-factor) estimate using rain data, Erodibility of soil (K-factor), Land Use/Cover (C-factor), Length and Steepness of soil slope (LS-factor) and the Practices of soil conservation factor (P-factor) have been estimated for the study area. Our findings reveal a substantial reduction in erosion rates – exceeding 50% – within areas undergoing forest landscape restoration compared to conventional croplands. Furthermore, our analysis indicates that erosion mitigation is particularly pronounced in forest plantations relative to other forms of FLR practices. These results not only offer valuable insights for policymakers and land managers to prioritise intervention efforts in vulnerable areas but also underscore the potential benefits of restoring forest landscapes within the TBVM. By elucidating the effectiveness of FLR in mitigating soil erosion, our study contribute to informed decisionmaking processes and underscores the importance of sustainable land management practices in safeguarding agricultural productivity and environmental resilience.

Keywords: Benin, GIS, remote sensing, soil erosion

Contact Address: Abiolla Robertson Kévin Amoussou, Leibniz Centre for Agricultural Landscape Research (ZALF), Müncheberg, Germany, e-mail: amoussoumatt@gmail.com

Sustainable intensification of smallholder crop-livestock farming systems in northern Ghana: Optimising groundnut plant density for grain and fodder

Nurudeen Abdul Rahman¹, Weseh Addah², Kubasari Joshua Adda², Bekele Hundie Kotu¹, Mateete Bekunda³

¹International Institute of Tropical Agriculture (IITA), Ghana

²University for Development Studies, Animal Science, Ghana

³International Institute of Tropical Agriculture (IITA), Uganda

The crop-livestock farming system is a common farming practice in West Africa with many technologies developed to intensify the system's productivity. However, there is limited literature on the assessment of the sustainability of integrated crop-livestock technologies at farm scale. Two on-farm trials (Agronomic trial and Livestock feeding trial) were conducted for two years (2017-2018) to identify a groundnut plant density that would be suitable, particularly for food (grain yield) and feed (fodder). Experiment I had four groundnut plant densities (22, 15, 11 and 9 (farmer practice) plants/m²) laid in RCBD with eight replications per treatment whilst the experiment II had the same four plant densities as treatments laid in RCBD with three replications per treatment. We applied the Sustainable Intensification Assessment Framework (SIAF) to compare the sustainability of the above treatments. The SIAF measures the sustainability of agricultural technologies based on five domains: productivity, economic, environment, human and social. We conducted the assessment in three steps: (I) Measured selected indicators from the five SIAF domains which were useful to answering research question, (II) Converted measured values of the indicators into scores using a scale of 0–1 and (III) Aggregated the scores under each domain and calculated sustainability index (SI) using geometric rules considering each SIAF domain as an edge of a pentagon. Specific indicators by domain measured were grain and fodder yields, weed biomass and livestock (Sheep) body weight (productivity), profitability (economic), vegetative cover, biological nitrogen fixation, leaf spot disease incidence and manure quality (environment), food security and nutrition (human) and technology rating by gender (social). The SI for 22 plants/m² increased by 82–215% compared with that of the other treatments and was greater than one (above maximum score limit) indicating better SI relative to the other treatments. We recommend that planting groundnut at a density of 22 plants/m² will enhance the sustainability of smallholder crop-livestock farming system in northern Ghana and similar agro-ecologies through its effect on productivity, income, food security, nutrition, and gender equity.

Keywords: Arachis hypogaea, plant density, savannah, smallholder farmers

Contact Address: Nurudeen Abdul Rahman, International Institute of Tropical Agriculture (IITA), Education Ridge, 0233 Tamale, Ghana, e-mail: n.abdulrahman@cgiar.org

Investigating roles of sustainable intensification practices in Ghana cropping systems using crop modelling approaches

Thuy Huu Nguyen¹, Bright Sallah Freduah², Amit Kumar Srivastava³, Jesse B. Naab⁴, Madina Diancoumba³, Dilys Sefakor Maccarthy², Samuel Kwasi Godfried Adiku², Heidi Webber³, Thomas Gaiser¹

¹University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany

²*University of Ghana, Soil and Irrigation Research Centre, Ghana*

³Leibniz Center for Agricultural Landscape Research (ZALF), Germany

⁴West African Science Service Center for Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

Successful upscaling of sustainable intensification (SI) practices from specific locations to regional scales requires further investigating the suitability of SI, especially under highly spatial and temporal heterogeneity of soil, seasonal climatic characteristics, and local inputs (e.g. fertilisers and residues). Understanding of SI performance across locations could be based on comprehensive field trials which are often lacking in Africa. In such a backdrop, dynamic crop modelling systems incorporating SI practices [e.g. crop residue retention or varied nitrogen (N) and phosphate (P) applications in crop rotation system] theoretically offer opportunities to investigate the effects of those SI practices on crop yield and soil nutrients (including mineral N, soil organic carbon, and total nitrogen). In this study, we used two crop growth models (SIMPLACE <LINTUL5> and APSIM) along with the existing field measured data for the maize-sovbean rotation system in northern Ghana. Changes in simulated yield and soil nutrients corresponding with step-wise incremental changes of previous crop residues (0, 25%, 75%, and 100%) as well as applied N (0, 30, 60, and 90 kg)N ha⁻¹) and P (0, 15, and 30 kg P_2O_5 ha⁻¹) were evaluated. The calibration of both crop models relied on the biomass and grain yield measurements from the 2010 sole maize crop. Compared to the observed biomass data, bias errors were recorded at 0.314 and 0.328 ton ha⁻¹ for LINTUL5 and APSIM, respectively. During validation across different years, both models consistently overestimated biomass and yield in 2011 and 2012, with bias errors around 0.9 ton ha^{-1} , while underestimating grain yield by approximately 0.5 ton ha⁻¹ in 2013. The LINTUL5 model successfully captured the positive impact of crop rotation (soybean-maize-soybean-maize) on maize grain yield. Nonetheless, it was noted that the observed increase in maize grain yield after rotation seasons was higher than the simulated yield increment within this model. These findings indicate the necessity of considering the spatial variations in crop residue retention and chemical fertilisation inputs in the farmer fields while upscaling model applications from field to regional scales.

Keywords: Chemical fertiliser, crop models, crop residue, crop rotation, maize-soybean, simulation

Contact Address: Thuy Huu Nguyen, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Katzenburgweg 5, 53115 Bonn, Germany, e-mail: tngu@uni-bonn.de

Impact of fertiliser applications on grain and vegetable crops in smallholder mixed crop-livestock systems in West Africa

Albert Berdjour 1,2 , Amit Kumar Srivastava 2 , Thomas Gaiser 2 , Safiétou Sanfo 1 , Bocar Ahamadou 3

¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Climate Change and Sustainable Agriculture, Mali

²University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany

³Institut Polytechnique Rural de Formation et de Recherche Appliquée (IPR/IFRA) de Katibougou, Mali

Mixed crop-livestock (MCL) systems can enhance crop yield, and improve nutrient cycling while reducing chemical fertiliser use. However, only a limited number of studies that reported this assumption were conducted under real-world farmer's conditions or followed an integrated approach. Therefore, a survey was conducted in the 2021/2022 and 2022/2023 cropping seasons in Ghana and Burkina Faso, respectively, to determine the impact of fertiliser application practices on the yield of grain and vegetable crops in MCL systems. Detailed information on fertiliser management practice and yield was collected from 317 MCL system farms distributed across three (3) districts/ provinces in the Upper East region of Ghana and Plateau central of Burkina Faso, respectively, summarising data on their grain and vegetable yields under (1) major fertiliser sources; organic, chemical, and combined (organic + chemical), (2) N fertiliser rate (crop × country specific N kg/ha recommendation), (3) application timing of fertiliser sources (recommended crop × country specific time of application), and (4) fertiliser placement methods (broadcast versus side placement versus furrow). Results show that the use of different fertiliser source increased (p < 0.05) vields of all grain crops (in Burkina Faso) and maize, rice, sorghum, millet, cowpea and all vegetable crops (in Ghana). The application of crop and country specific recommended N rates significantly influenced (p < 0.05) yields of sorghum, cowpea and green beans in Burkina Faso and rice, sorghum, millet, cowpea and pepper in Ghana compared to low N application rates. The contribution of manure application timing on yield mostly differed between countries, such that high tendencies of increased yields were recorded when manure was applied for 0 to 3 weeks before planting (WABP) in Burkina Faso, while in Ghana, the highest yield improvements were observed when application periods exceeded 3 WABP. Not broadcasting fertiliser only increased (p < 0.05) yields of millet and green beans (in Burkina Faso) and vegetable crops in both countries. These results help improve our understanding of fertiliser practices in MCL systems of Ghana and Burkina Faso, and may help guide fertiliser management in these countries and similar ecologies in West Africa.

Keywords: Fertiliser application, mixed crop-livestock systems, vegetable crops

Contact Address: Albert Berdjour, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Climate Change and Sustainable Agriculture, Bp E 423, Bamako, Mali, e-mail: berdjour.a@edu.wascal.org

Pest, diseases and control options

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When and where to warn farmers: Analysing the value of spatio-temporal pest risk prediction for pest monitoring decisions

Johannes Kopton¹, Sytze de Bruin², Dario Schulz³, Eike Luedeling¹

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

²Wageningen University & Research, Lab. of Geo-Information Science and Remote Sensing, The Netherlands

³European Forest Institute, Bonn, Germany

Plant pests cause significant pre-harvest loss in Indian vegetable production, threatening food security and rural livelihoods. To mitigate yield loss while avoiding excessive pesticide use, careful monitoring of crops is necessary for timely and targeted damage prevention or treatment. However, in-field monitoring is not free. Monitoring each field every day risks wasting resources and precious time needed for other management tasks. We present a novel and scalable disease risk forecasting method to assess when and where it is useful to look for symptoms. Infestation probabilities are predicted using sparse Gaussian process classification with deep kernel learning. Both abiotic suitability and spatio-temporal diffusion effects are exploited for prediction. Data inputs are crowdsourced infestation data observed via the Plantix smartphone app (case study: n=68,586), as well as daily weather records. The predictions are then used to calculate the Value of Information (VoI) for pest monitoring via a probabilistic decision model. We present two types of spatio-temporal VoI measures: individual VoI for assessing the benefits to the individual farmer, and community VoI to include the potential value generated by warning nearby farmers against disease outbreaks. As a case study, we examine the invasive pest *Tuta absoluta* in tomato production in Andhra Pradesh over a timespan of 6 years (2018 to 2023). Farmers' current practices (calendar-based monitoring and pesticide application) are compared to the proposed VoI-based practice in terms of yield loss, farm profitability and pesticide use. We find that monitoring tomato plants for symptoms of T. absoluta infestation is of significant value both to the respective farm itself and to its spatial neighbourhood. Automated warnings based on our pest risk prediction model could improve pest management efficiency at plot-, farm-, and regional scale.

Keywords: Decision analysis, India, insect pests, tomato, Tuta absoluta

Contact Address: Johannes Kopton, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Auf dem hügel 6, 53121 Bonn, Germany, e-mail: kopton@uni-bonn.de

Invasive plant species drive land use changes in East Africa

Kai Behn¹, Hellen Kamiri², Daisy Mutuku¹, Meschack Ndikumwenayo¹, Bernice Sainepo¹, Mathias Becker¹

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

²Karatina University, Dept. of Agricultural Sciences, School of Agriculture and Biotechnology, Kenya

Invasive alien plant species affect biodiversity, agriculture, and rural livelihoods. For instance, in Baringo County, Kenya, the leguminous tree Prosopis juliflora was introduced in the 1980s to combat desertification, but has since invaded the fringes of Lake Baringo and rangelands with shallow water tables, threatening traditional resource management and inducing land system changes. Recently, with the annual Asteraceae Parthenium hysterophorus, another invasive species is rapidly spreading in Baringo. With combined household interviews, surveys on biomass and vegetation dynamics, and soil analyses we assessed interactions between invasive species and land-use changes. In the face of two consecutive waves of plant invasion, we (1) present a conceptual model of related land system shifts, (2) analyse biophysical factors determining spatial and temporal variations in invasive species spread dynamics, and (3) provide examples for changing agronomic practices. The rapid spread of Prosopis in the 2000s led to degradation and scarcity of grazing land, and restricted physical access to water for livestock, eventually affecting pastoral livelihoods. This had driven a shift to agro-pastoralism and commercial crop faming on land cleared from Prosopis. While land use intensification has partly eased problems associated with *Prosopis*, it appears to facilitate the spread of Parthenium. Hence, farmers in rainfed systems with seasonal fallows and pastoralists in rangelands report Prosopis as a key constraint, while crop farmers using irrigation and continuous cultivation report *Parthenium* to have recently developed into the main problem weed reducing crop performances in Baringo. Elevated soil moisture in irrigated land, an increased use of agricultural machinery, and seed dispersal in irrigation channels appear to accelerate the spread of *Parthenium*. The spread of both invasive species may drive further agricultural intensification with increasing pesticide use, the spatial separation of crop farming and livestock rearing and the replacement of farmyard manure by mineral fertilisers. The severe precipitation events in the El Nino year of 2023/24 have accelerated the spread of Parthenium, but may also favour a re-invasion by Prosopis of formerly cleared crop and rangelands. Our results show the need and indicate solutions for adapted sustainable land use systems and agronomic practices to halt and counteract invasive species.

Keywords: Kenya, *Parthenium hysterophorus, Prosopis juliflora,* system shifts, vegetation dynamics

Contact Address: Kai Behn, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Bonn, Germany, e-mail: kaibehn@uni-bonn.de

The fungus *Ceratobasidium theobromae* causes a severe disease of cassava in Southeast Asia, the cassava witches' broom disease

Samar Sheat¹, Willmer Cuellar², Jonathan Newby³, Stephan Winter¹

¹Leibniz Institute DSMZ - German Collection of Microorganisms and Cell Cultures, Plant Virus Department, Germany

²The Alliance of Bioversity International & CIAT, Cassava Program, Laos

³*The Alliance of Bioversity International & CIAT, Virology and Crop Protection Group, Colombia*

Cassava witches' broom disease (CWBD) is a severe disease affecting cassava (Manihot esculenta) cultivation in Southeast Asia (SEA). Infected cassava plants display symptoms such as reduced internodal length, increased leaf proliferation, and stem weakening, which collectively lead to poor germination of infected stem cuttings and marked reductions in both fresh root yields and starch content. Consequently, CWBD inflicts substantial economic losses on both farmers and processors. Recent research conducted by the International Center for Tropical Agriculture (CIAT) teams in Laos and Colombia has elucidated a strong association between a fungus, Ceratobasidium theobromae and the symptomatic manifestations of CWBD. Notably, this fungus has been consistently identified in diseased samples since the initial outbreaks of CWBD in SEA and was transmissible by grafting. Since no other pathogens including phytoplasmas were detected in the affected plants, a fungal aetiology of the disease can be assumed. Utilizing RNAscope® in situ hybridisation, the pathogen was traced in the xylem tissues of stems, leaves, and petioles, as well as in the epidermis of stems. Additionally, the distribution of *C. theobromae* was found to be heterogeneous along the cassava stem, with a concentration in symptomatic areas. This uneven distribution indicates that the pathogen does not systemically infect the plant, thereby allowing the possibility of obtaining healthy planting material from asymptomatic sections of an infected plant. These insights are critical for advancing our understanding of CWBD epidemiology and developing effective disease management strategies. Such strategies are imperative to prevent the further spread of CWBD and mitigate the risk of introducing the disease to cassava-growing regions in Africa and the Americas through the international movement of planting materials. Current management efforts focus on refining quarantine protocols and ensuring the production and dissemination of pathogen-free planting material to control the spread of the disease.

Keywords: Cassava, pathogens, Southeast Asia

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

Abundance and species diversity of predatory arthropods in potato plants with application of botanical pesticides

Ruth Stella Thei, Muhammad Sarjan, Taufik Fauzi Mataram University, Agroecotechnology, Indonesia

Potato is one of the most important vegetable commodities and has high economic value and is a plant with great potential as a horticultural crop that can support world food diversification. It is also the fourth leading food commodity in the world after rice, corn and wheat. The need for potatoes continues to increase every year, but potato production has not been able to meet market demand which increases every year. In Indonesia they are generally grown in high altitudes with relatively large rainfall. Therefore the use of pesticides in potato farming is very high. The unwise use of synthetic pesticides can cause losses, such as water and air pollution, poisoning in both humans and livestock, killing natural enemies, pest resurgence, accumulation of pesticide residues, and increased production costs. One alternative that can be applied to replace the use of chemical pesticides is the use of plant-based pesticides, so this research was conducted with the objectives to compare the species diversity and abundance of predatory arthropods in potatos plants applied with botanical insecticide and synthetic insecticide. The experiment was carried out in Sembalun Vilage, East Lombok (Indonesia), which was arranged using Randomised Block Design consisting of 4 treatments namely control, abamectin 0,5 ml, virginia tobacco stem waste pesticide 10 ml and neem botanical pesticide 50 ml. The result showed that 26 species of 18 families of predatory arthropods were found on potato during a planting period. The highest species diversity for spider and predatory insect was found on potato spraved by neem inesctiside. The lowest predator population abundance were found on synthetic pesticide sprayed potato and they were significantly different from those botanical pesticide -potato plots. The most abundant spiders and predatory insect were found on potato plants sprayed with neem insecticide.

Keywords: Botanical insecticide, diversity, potato plant, predatory arthropods

Contact Address: Ruth Stella Thei, Mataram University, Agroecotechnology, Jl. majapahit 62, 83115 Mataram, Indonesia, e-mail: ruth.stella@unram.ac.id

Maximizing the benefits of push-pull technology with pigeon pea integration

Sylvia Buleti, Shem Kuyah

Jomo Kenyatta University of Agriculture and Technology, Kenya

Constrained crop production in smallholder systems in Africa is highly associated with poor soil fertility, agricultural pests and the ravages of climate change. The poor soil fertility is a consequence of continuous cropping, poor biomass production and extractive agriculture. A promising strategy for mitigating these constraints is crop diversification with resilient varieties. A needs assessment with 10 focus group discussions and key informant interviews was conducted in Western Kenya to identify promising crops and cropping systems for further intensification of push-pull technology, poly-cropping system that comprises of cereals (e.g., maize) intercropped with a repellant plant (*Desmodium*) and a trap plant (Napier grass or *Brachiaria*) on the border.

Legume integration with pigeon pea was ranked best because of the potential of the crop to provide firewood, fodder, edible grain, and income; and to do well under dryland conditions. Field experiments were established up in Kisumu, Siaya and Vihiga counties in western Kenya to determine the effect of integrating pigeon pea in push-pull. Crop yield and growth of pigeon pea was monitored for four seasons in four treatments established in 2021: (1) push-pull: maize+*desmodium*+*brachiaria*, (2) intensified push-pull: pushpull+pigeonpea, (3) maize+pigeon pea, and (4) maize monocrop). Maize stover and grain yield were not significantly different across the treatments and sites, suggesting that integration of pigeon pea did not affect the main crop. However, variations were noted in the seasons. Push-pull+pigeon pea performed best for stover yield in Siaya and in season 3; and push-pull plots with pigeon pea had higher maize grain yield in season 3. The growth of pigeon pea varied across treatments with push-pull+pigeon pea performing better than maize+pigeon pea. Fresh leaf and twig weight (sources of fodder and fuelwood) were the same in both treatments. We conclude that that intensification of push-pull with pigeon pea maximises the performance of push-pull technology.

Keywords: Biomass, firewood, fodder, grain legume

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

Economic viability and impact of Lalguard Java bioinsecticide on the biological control of the whitefly on common bean

Alcido Elenor Wander, Osmira Fatima Da Silva, Eliane Dias Quintela Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

The bioinsecticide Lalguard Java, developed in a public-private partnership between Embrapa and Lallemand Plant Care, was registered at the Brazilian Ministry of Agriculture in August 2022 to control the whitefly (Bemisia tabaci). The whitefly attacks several crops in Brazil, including common beans (*Phase*olus vulgaris L.), soybeans (Glycine max), and cotton (Gossypium hirsutum L.). In 2023, technical coefficients in the main common bean-producing regions in the 3rd harvest season were surveyed to measure the impact and economic benefit of the new bioinsecticide. The input and product prices were from 3rd April 2023 (USD 1.00 = BRL 5.0637) and 1^{st} September 2023 (USD 1.00 = BRL4.9312), respectively. The average yield of common beans (cultivar Pérola) with Lalguard Java was 2,880 kg ha⁻¹, at a production cost of USD 1,402.66 (BRL 7.102.63) ha⁻¹. In the conventional cropping system, using chemical insecticides, the farmers' production costs were USD 1,472.93 (BRL 7,458.47) ha^{-1} , a higher cost to obtain the same yield of 2,880 kg ha^{-1} . The average unit cost of a kg of common beans in the conventional cropping system was USD 0.51 (BRL 2.59), and with Lalguard Java, it was USD 0.49 (BRL 2.47) (-4,77%). The new bioinsecticide provided farmers with a profitability of 62%with the cropping system; for those who used the conventional system, the profit was 54%. The regional economic benefit for society via agribusiness was USD 1,226,735.89 (BRL 6,049,280.00), given the cost reduction, the adoption area of 34,000 ha and Embrapa's 50% participation in the research and development of this technological innovation.

Keywords: Economic benefit, production cost, yield

Contact Address: Alcido Elenor Wander, Brazilian Agricultural Research Corporation (EM-BRAPA), Rodovia GO-462, km 12, 75375-000 Santo Antonio de Goias, Brazil, e-mail: alcido.wander@embrapa.br

Sustainable weed control through fatty acids as bioherbicide: A study on photosynthesis inhibition and seed germination

Farimah Asadi¹, Michael Petry², Thorstan Kraska¹

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

²PETRYmade Oberflächentechnik, Germany

Resource accessibility has become increasingly scarce as the global population grows, making sustainable food production more challenging. 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; however, their harmful environmental effects require sustainable alternatives. Fatty acid compounds, primarily derived from glyceric plant oils, are one such alternative. These natural products have low ecotoxicological side effects and high biodegradability, making them promising alternatives to chemical herbicides. This study aimed to evaluate the herbicidal effects of an oil-in-water emulsion preparation containing various fatty acid compounds on the photosynthesis of green beans and germination of tomato seeds as model plants. In the first phase, a laboratory experiment assessed the inhibitory effect of fatty acids with different carbon chain lengths on tomato seed germination. In the second phase, greenhouse experiments were performed using green beans to determine the phytotoxicity of the compounds. The results showed that pelargonic acid had high phytotoxic effects on green beans at concentrations of 1% and higher, whereas caprylic acid was effective even at lower concentrations (0.5%). Both compounds exhibited signs of damage at the lowest concentration (0.1%)and death occurred as the concentration increased. Linseed oil (containing linolenic acid as the main fatty acid) also showed the potential to exert different levels of phytotoxicity but not as strongly as other compounds. The experiments showed that the dose and length of the carbon atom chain of the fatty acids could determine the effect intensity. Our study emphasised the potential of fatty acid derivatives as pre-and post-emergence herbicides for sustainable weed control. By incorporating these natural compounds into integrated weed management strategies, farmers can reduce crop stress and promote sustainable food production to meet the demands of the growing population.

Keywords: Biorationals, integrated weed management

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

Effective control of insect pests' population in stored rice using LED attractants

Carlito Balingbing¹, Nguyen Van Hung¹, Sascha Kirchner², Oliver Hensel²

¹International Rice Research Institute, Philippines ²University of Kassel Agricultural and Risourtems Engineering, (

 $^{2}\mbox{University}$ of Kassel, Agricultural and Biosystems Engineering, Germany

Stored grain products are prone to insect infestations especially in tropical environments where traditional storage systems are commonly used by farmers and rice processors. Physical attractants such as light emitting diodes (LEDs, 5mm 5VDC) have been tested to effectively decrease insect population in rice storage by naturally luring the insects into a trap. A 1-ton GrainSafeTM storage system (replicated 3 times) filled with rice paddy (MC: 12%+1%) that is heavily infested with storage insect pests such as Rhyzopertha dominica, Sitophilus oryzae and Tribolium castaneum, with population densities (no. of adult insects/ton) of 101,444; 27,777; and 11,666, respectively, were used to deploy the two-coloured LEDs (blue and red) and a control treatment. A Completely Randomised Design (CRD) experimental set-up was implemented to capture storage insect pests on a daily basis through an improvised trap fitted with the LED attractant device and manually counting and identifying the number of insects trapped per day with the aid of a magnifying lens (LU-MENO Lupenleuchte 8245-PRO). The blue LED effectively lured the major insect pests and the mean capture rates (insects trapped per day/total density, %) were determined at 0.33, 0.11, and 0.11, that are equivalent to 354, 9 and 33 average insects trapped per day, respectively, for R. dominica, S. oryzae, and T. castaneum. The red LED recorded capture rates of 0.03, 0.08, and 0.02, respectively for each insect, are equivalent to 27, 7 and 5 insects trapped per day. On the other hand, the control treatment exhibited capture rates of 0.0, 0.02, and 0.04, respectively for each insect are equivalent to 2, 4 and 10 insects trapped per day. The number of insects lured and capture rates are significantly different (at α =5%) in the two LEDs attractants and the control treatment (p-value=0.0000). The use of blue and red LEDs can significantly reduce storage insect populations by effectively luring the insects into a trap which is a sustainable method to eradicate insect pests in stored grains because these are chemical-free attractants.

Keywords: Chemical-free attractants, insect pests, LED, stored rice

Contact Address: Carlito Balingbing, International Rice Research Institute, Sustainable Impact through Rice-based Systems, 4030 Los Baños, Philippines, e-mail: c.balingbing@irri.org

Farmers' innovation–decision processes and adoption dynamics surrounding push-pull technology in western Kenya

Olufemi Adesina¹, Stephen Whitfield¹, Susannah Sallu¹, Steven Sait², Jimmy Pittchar³

¹University of Leeds, School of Earth and Environment, United Kingdom ²University of Leeds, School of Biology, United Kingdom

³International Centre of Insect Physiology and Ecology, Kenya

Smallholder farmers in sub-Saharan Africa (SSA) face increasing challenges, from pests and climate change to degraded soils, among other issues. In response to these challenges, international agricultural research for development (R4D) investment is often focused on developing and scaling up techniques and technologies that bolster resilience. However, such approaches are often technocentric and follow linear assumptions of innovation diffusion and adoption, which overlook the complex realities that influence smallholder farmers' dynamic decisions and engagement with novel techniques. This study used qualitative ethnographic methods to explore the experiences, knowledge construction, motivations, and decision-making of farmers in western Kenya regarding the extensively researched push-pull technology (PPT). Findings reveal that motives for practising PPT evolve as farmers respond to emerging realities. Furthermore, farmers modify and adapt PPT components to meet diverse motivations in changing contexts rather than simply adopting the practice as taught or shown. Contextual factors such as health, land tenure, access to information and inputs, cost/benefit trade-offs, interactions and social dynamics interact in complex ways. These complex dynamics question the prevailing notions of innovation success based on aggregate adoption indicators. Ultimately, sustaining African food systems requires moving beyond technocratic approaches to nurturing context-specific, farmer-centric innovation pathways that recognise smallholders' ingenuity in navigating heterogeneous realities. Innovation unfolds as a dynamic process requiring inclusive participation, flexibility for local adaptation, and longterm collaboration with farmers as partners in finding solutions. This study provides more holistic approaches to agricultural research and development in Africa, placing farmers' various contexts and active participation at the core of innovation processes.

Keywords: Agricultural innovation, biocontrol, push-pull technology

Contact Address: Olufemi Adesina, University of Leeds, School of Earth and Environment, Woodhouse Leeds LS2 9JT, Leeds, United Kingdom, e-mail: eeosa@leeds.ac.uk

Synthetic polyploidisation promising tool in crop management: Induces enhanced phytochemical profile and biological activities in *Thymus vulgaris*

NEHA GUPTA¹, SOHAM BHATTACHARYA², ELOY FERNÁNDEZ CUSIMAMANI¹ ¹Czech University of Life Sciences, Fac. of Tropical AgriSciences / Dept. of Crop Sciences and Agroforestry, Czech Republic

²Czech University of Life Sciences, Fac. of Agrobiology, Food and Natural Resources / Dept. of Agroecology and Plant Production, Czech Republic

Consumption of medicinal and aromatic plants is broadening and boosting globally. However, the primary supply of raw materials in developing nations due to wild harvesting is destroying habitats, resulting in a loss of genetic diversity. This situation makes the development and application of breeding programmes imperative. Polyploidisation has emerged as a promising tool in plant breeding and crop management to generate genotypes with novel genetic combinations that can confer enhanced desirable biochemical, morphological, physiological, and biological and increased resistance to both biotic and abiotic stresses. Polyploidisation in medicinally and economically important herbs has a plethora of benefits. Essential oil from Thymus vulgaris L. has valuable therapeutic potential that is highly desired in the pharmaceutical, food, and cosmetic industries. Considering these advantages and the rising market demand, induced polyploids were obtained using oryzalin to enhance essential oil yield. However, their therapeutic values were unexplored. So, this study aims to assess the phytochemical content, and antimicrobial, antioxidant, and anti-inflammatory activities of tetraploid and diploid thyme essential oils. Induced tetraploids were found to have higher essential oil yield with enhanced thymol and γ -terpinene content than diploid. Tetraploids exhibited higher antibacterial activity against respiratory pathogens than the diploid. Similarly, in DPPH radical scavenging assay tetraploid essential oil was more potent than diploid. Tetraploids exhibited more effective inhibition of in vitro catalytic activity of the pro-inflammatory enzyme cyclooxygenase-2 (COX-2) than diploids. In conclusion, these results suggest that synthetic polyploidisation using oryzalin could effectively enhance the quality and quantity of secondary metabolites, produce genotypes that are highly tolerant to abiotic and biotic stress, and develop more efficient essential oil-based commercial products using this induced genotype.

Keywords: Medicinal plants, plant breeding, polyploidisation, thyme

Contact Address: Neha Gupta, Czech University of Life Sciences, Fac. of Tropical AgriSciences / Dept. of Crop Sciences and Agroforestry, Kamycka 129 Suchdol, 16500 Prague, Czech Republic, e-mail: guptan@ftz.czu.cz

Farmers' knowledge of fall armyworm, and factors influencing the choice of control method in Benin

Tamegnon Hospice Tossou¹, Jan Henning Sommer¹, Manuele Tamò², Christian Borgemeister¹

¹University of Bonn, Center for Development Research (ZEF), Ecology and Natural Resource Management, Germany

²International Institute of Tropical Agriculture (IITA), Biorisk Management Facility (BIMAF), Benin

The fall armyworm (Spodoptera frugiperda) causes production losses of around 49% in maize production in Benin, where it has been recorded for the first time in 2016. This represents a threat to farmers and to the food security of the population, for whom maize is a key food. We evaluated the perception and management practice of maize farmers in Benin's southern agricultural zone farmers vis-a-vis S. frugiperda by conducting a survey using a semi structured questionnaire of 242 farmers in four maize growing departments: Atlantique, Zou, Couffo and Plateau from Sep to Nov of 2023. We found that 93 % of farmers have a broad knowledge of the S. frugiperda pest and 95% believe that they are victims of its infestations and that S. frugiperda is very dangerous. Farmers reported that *S. frugiperda* causes more damage to the leaves of maize (88.8%) and the symptoms could be morphologically recognised by farmers, varying by department: Plateau (91.2%), Zou (96.6%) Atlantique (96.8%) and Couffo (100%). In 2020, farmers estimated a yield loss of 29%. The situation worsened in 2021, with more maize lost (30% of production). By 2022, farmers seem to have taken control of the situation, with a 6% reduction in damage. 73% of farmers spray synthetic chemicals, 2,5% cultural practices, 12,9% any method while only 1.2% use botanical extracts. The variables that determined the use of a control mean by farmers were: year of experience in maize production, availability of financial resources and, to a lesser extent, the effectiveness of the control method. Logistic regression showed that the propensity for each farmer to use a control method against S. frugiperda increased when they had much more experience in maize production and when financial resources were available, and only if the farmer felt that the method was effective. Research and agricultural extension services should consider those factors in the development of any sustainable management of *S. frugiperda* programme in Benin.

Keywords: Perception, Spodoptera frugiperda, sub-Saharan Africa, Zea mays

Contact Address: Tamegnon Hospice Tossou, University of Bonn, Center for Development Research (ZEF), Ecology and Natural Resource Management, Genscherallee 3, 53113 Bonn, Germany, e-mail: tamegnon@uni-bonn.de

Survival of rhizobacteria (RMT2NF4) with cyantraniliprole on agar medium

NICHAKARN POTA¹, TAWANCHAI KHUENDEE¹, NARIN IAMTHONGIN¹, JEERANAN KHOMAMPAI¹, NUTTAPON KHONGDEE², YUPA CHROMKAEW¹ ¹Chiang Mai University, Dept. of Plant and Soil Science, Thailand ²Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand

In Thailand, sweet corn is a significant crop for the economy. It is grown over much of Thailand, particularly in the north. However, both quality and quantity are needed to produce sweet corn. Large amounts of chemical pesticides and fertilisers are therefore required. The fall armyworm damages sweet corn during early cultivation, which lowers yields. Therefore, it is imperative to use insecticides belonging to the cyantraniliprole group-a class of substances that the Department of Agriculture recommends. This study evaluated the survival of rhizobacteria (RMT2NF4) in the presence of the insecticide cyantraniliprole on nutrient agar and nutrient broth media. The research was conducted at the Soil Microbiology Laboratory, Faculty of Agriculture, Chiang Mai University, from June 2023 to March 2024. The objective was to assess the survival rate of RMT2NF4 rhizobacteria when exposed to varying concentrations of cyantraniliprole across seven levels in nutrient agar and broth cultures. The results demonstrated that RMT2NF4 rhizobacteria could grow on all media treatments containing cyantraniliprole. On nutrient agar, the highest microbial population of 3.4×10^7 cfu ml⁻¹ was observed at a cyantraniliprole concentration of 3 ml l⁻¹. Notably, in nutrient broth, the peak microbial population of 8.6×10^6 cfu ml⁻¹ was attained with a higher cyantraniliprole concentration of 25 ml l⁻¹. Overall, the survival rate of RMT2NF4 rhizobacteria ranged from 10⁶ to 10⁷ cfu ml⁻¹ across the tested cyantraniliprole concentrations in both media types. These findings indicate that RMT2NF4 rhizobacteria can coexist with cyantraniliprole, suggesting compatibility between this bacterial strain and the insecticide. Based on their demonstrated survival, further investigations can be pursued to evaluate the potential of RMT2NF4 rhizobacteria in promoting plant growth when applied alongside cyantraniliprole in subsequent laboratory experiments.

Keywords: Insecticide, PGPR, sweet corn

Contact Address: Yupa Chromkaew, Chiang Mai University, Dept. of Plant and Soil Science, Huay Kaew Road, Muang District, 50200 Chiang Mai, Thailand, e-mail: yupa.c@cmu.ac.th

Innovative agroecology practices improve maize and bean yields in nutrient-deficient sandy soils of Makueni, Kenya

PETER BOLO¹, HEZEKIAH KORIR², BEATRICE ADOYO³, ANNE KURIA³, LISA FUCHS³ ¹The Alliance of Bioversity International & CIAT, Multifunctional Landscapes, Kenya

²International Institute for Tropical Agriculture (IITA), Environmental Sciences and Education, Kenya

³*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya*

Agroecology has been highlighted as a sustainable approach with the potential to support food system transformation in both low and middle-income countries. Its potential to improve soil and crop productivity is unmatched. Implementation of innovative agroecology practices is key in promoting soil quality and health, improving agrobiodiversity and enhancing crop productivity.

We assessed the influences of select agroecology practices on maize and bean crop performance in nutrient deficient sandy soils in Makueni County, Kenya. The study was conducted on 30 resource-constrained smallholder farms during the short rains season of the year 2023. The innovative agroecology practices tested involved; i) use of biopesticides (IPM); ii) terracing, and iii) use of organic inputs (manure). The three agroecology practices geared towards pest (IPM), water (terraces) and soil (manure) management. We present the results of one cropping season.

Preliminary results show that agroecological practices involving combined use of biopesticides and organic inputs increased maize and bean yields relative to the rest of the practices. Across the three agroecology practices implemented, maize yields increased by at least 40 kilograms. Relative to control plots, maize yields increased by 109, 78 and 40 kilograms per acre respectively under terraces, manure and IPM practices, respectively. This was consistent to monetary gains averaging USD\$ 50.26, 63.14 and 18.28 per acre in one season under terraces, manure and IPM, respectively. Similarly, increased by 20.7, 33.3 and 19.8 kilograms per acre per season, respectively under IPM, Manure and terraces. These were equivalent to monetary gains of USD\$ 25.48, 40.98 and 24.37, respectively under IPM, manure and terraces.

These results provide preliminary evidence to support the promotion of agroecological practices among farmers and policy makers. In addition, the outcomes indicate that agroecological practices are effective in boosting crop performance, underpinning the possibility to attain improved productivity and sustainability through integration of agroecology practices. Finally, farmers can effectively and cheaply manage crop pests through the use of biopesticides that reduces dependence on harmful and expensive chemical pesticides.

Keywords: Agroecology, bean yield, crop performance, integrated pest management, maize yield, soil management, water management

Contact Address: Peter Bolo, The Alliance of Bioversity International & CIAT, PO Box 25-40611 Nyilima, Kisumu, Kenya, e-mail: p.bolo@cgiar.org

Agro-ecological approaches for fruit and vegetable production systems: Opportunities and boundaries in Turkana county, Kenya

Alex Eeman Aule¹, Irmgard Jordan², Lydiah Maruti Waswa³, Peter Edome Akwee¹, Godfrey Nakitare Nambafu¹, Gudrun B. Keding⁴

¹Turkana University College, Biological and Physical Science, Kenya
²The Alliance of Bioversity International & CIAT, Kenya
³Egerton University, Dept. of Human Nutrition, Kenya
⁴Justus Liebig University Giessen, Dept. of Nutritional Sciences, Germany

Eastern African Drylands, including Turkana County, experience frequent droughts and occasional heavy rains, posing challenges to fruit and vegetable production, consequently affecting people's nutritional status. This study, which focused on agroecological methods for fruit and vegetable production systems, was carried out within the scope of the ustainable Food Environment for Food and Nutrition Security in Eastern African Drylandsproject. The study used trials of improved practices (TIPs), engaging 50 farmers in two community units: Kabulokor (mainly agro- pastoralist) and Atala Kamusio (mainly pastoralist). Twelve gender-disaggregated Focus Group Discussions (FGD) were conducted to inform the TIPs. During the FGDs, participants discussed promising agro-ecological methods to enhance fruit and vegetable production on their farms. For TIPs, 50 agro-pastoralist households were randomly selected to participate. Farmers chose their preferred agro-ecological method out of a list of 7 to enhance vegetable or fruit production. Data was collected during each of the three visits in the TIPs process which lasted three-month. The study revealed that farmers initially selected multiple agro-ecological methods such as mulching, applying ash as pest management, early hand weeding and tree planting. However, later most farmers focused on specific techniques, mainly intercropping, pest management by ash and applying animal manure. Follow-up workshops to gather farmers' opinions on the outcome showed participants were 1) unfamiliar with important agricultural practices, like mulching, 2) intercropping as a farming practice, was restricted to cowpea, kales with maize and Sorghum for some due to lack of seeds, 3) they relied on seeds that they bought from agro vets. 90% of the participants showed lack of knowledge in bottle irrigation techniques. Restricted access to training and seeds underscores the importance of bolstering extension services and local seed production for agricultural sustainability and independence. Filling knowledge and resource gaps is essential to ensure effective and accessible production of fruits and vegetables in drylands, as demonstrated in previous projects. Findings from this study informs policymakers on fruitful agro-ecological methods, enhancing food security and sustainability at county and national levels.

Keywords: African drylands, food and nutrition security, fruits, vegetables

Contact Address: Gudrun B. Keding, Justus Liebig University Giessen, Dept. of Nutritional Sciences, Senckenbergstr. 3, 35390 Giessen, Germany, e-mail: Gudrun.Keding@fb09.uni-giessen.de

Enhancing crop systems classification through fusion of Planetscope and Sentinel-2A imagery using deep learning

Henry Kyalo, Tobias Landmann

International Centre of Insect Physiology and Ecology (icipe), Kenya

Classification of cropping systems is important for various applications such as agricultural monitoring and food security assessment, yield prediction, and crop health monitoring. Accurate classification allows for targeted interventions such as precise irrigation and fertiliser application, resulting to improved yields. Additionally, it allows draught monitoring and monitoring of crop rotation patterns and pest infestations. Accurate crop systems classification allows for identification of areas where crop diversification can be implemented. Growing a variety of crops improves the resilience to pests, diseases, and climate change, reducing the risk of crop failure and therefore ensuring a more stable food supply. Further, accurate crop systems classification helps policy makers and agricultural planners in allocation of resources more efficiently, which leads to higher yields per unit of input, increasing overall food production.

In this study, we propose a novel approach that fuses Sentinel-2A and Planetscope satellite imagery through a ResNet deep learning model to enhance the spatial and spectral resolution of Sentinel-2A for agricultural crop systems classification. For crop systems classification, image fusion is important for identification of different cropping systems, and is also useful in regions with frequent cloud cover. The trained model is used to predict Sentinel-2 images using Planetscope data as the reference, resulting in improved Sentinel images with finer details.

The predicted images are overlayed with ground truth data and spectral indices extracted from each point data and utilised for multivariate timeseries crop systems classification. The model performance is evaluated on overall accuracy and f1-score. Thereafter, maps based on the area of interest are generated, showing intensity and areas where monocrop and intercrop systems are most likely practised.

This study demonstrates the effectiveness of our proposed approach in improving crop systems classification through fusion of satellite imagery with deep learning techniques. The results highlight the potential for enhanced agricultural monitoring and decision-making, ultimately contributing to food security and sustainable agricultural practices.

Keywords: Classification, data fusion, deep learning, food security

Contact Address: Tobias Landmann, International Centre of Insect Physiology and Ecology (icipe), Icipe str. 1, 00100 Nairobi, Kenya, e-mail: tlandmann@icipe.org

Bioeconomy and Brazilian agribusiness: Perspectives and challenges of the national bioinputs program

RENATO DE SOUSA FARIA¹, ALCIDO ELENOR WANDER² ¹Federal University of Goiás, Graduate Program in Agribusiness, Brazil ²Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

The utilisation of bioinputs has gained prominence in both conventional and organic agricultural systems. In this context, this paper discusses sustainable development in Brazilian agribusiness through the National Bioinputs Program, aiming to reduce dependence on chemical inputs and increase sustainability in agricultural production. It addresses the bioeconomy as a new paradigm for agribusiness, highlighting the importance of technological innovations and the regulation of the sector to promote the use of bioinputs. From documental research and literature review, the study analyses the challenges and perspectives of this program. So far, there are 526 bioinputs registered in Brazil for phytosanitary control against various pests and diseases across different agricultural crops. These bioinputs span eleven classes, with only two lacking bioproducts suitable for organic agriculture: microbiological bactericides and pheromones. Despite the availability of bioinputs, their practical adoption remains limited. Factors contributing to this include financial constraints, inadequate awareness of their existence, and unfamiliarity with their application methods. As main challenges, we identified the need for public policies that encourage research and development, as well as regulation mechanisms that ensure the efficacy and safety of new bioinputs. Additionally, many farmers face financial limitations, hindering their ability to invest in bioinputs and their insufficient knowledge about bioinputs and their benefits impedes their widespread adoption. Farmers need guidance on the proper use of bioinputs to maximise their effectiveness. We conclude that, despite these identified challenges, the bioeconomy and associated development and use of bioinputs represents a significant opportunity for Brazilian agribusiness, promoting sustainability and competitiveness in the global scenario. Therefore, there is a need for increased awareness, financial support, and targeted education to fully harness potential of bioinputs.

Keywords: Bioeconomy, bioinputs, Brazilian agribusiness, public policy, sustainability

Contact Address: Alcido Elenor Wander, Brazilian Agricultural Research Corporation (EM-BRAPA), Rodovia GO-462, km 12, 75375-000 Santo Antonio de Goias, Brazil, e-mail: alcido.wander@embrapa.br

Characterisation of coffee pulp biochar and its impact on soil properties and microbial population

Piyaphad Ninlaphong¹, Sasiprapa Kullachonphuri¹, Phonlawat Soilueang¹, Yupa Chromkaew¹, Nuttapon Khongdee² ¹Chiang Mai University, Dept. of Plant and Soil Science, Thailand

²Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand

Different types of agricultural waste can produce biochar, but the waste material and burning method determine its properties. This study aimed to produce biochar from coffee pulp, which are readily available in northern Thailand, and investigate its effect on soil properties and microbial populations. The research was conducted at the Faculty of Agriculture, Chiang Mai University. The kiln method was used to convert coffee pulp into biochar, which was then studied for its physical and chemical properties using a Field Emission Scanning Electron Microscope (FE-SEM) coupled with an Energy Dispersive X-Ray detector. Additionally, the biochar was mixed with soil to assess its ability to improve soil quality. The experimental design employed was a Completely Randomised Design (CRD), comprising five treatments. These methods involved mixing coffee husk-derived biochar into soil at rates of 0, 2.5, 3.75, 5, and 7.5% of soil weight. The study found that the coffee biochar had a pore size of 48.35 μ m and contained carbon (66.60%), oxygen (19.13%), potassium (11.63%), molybdenum (1.43%), phosphorus (0.93%), chlorine (0.23%), and silicon (0.07%). Mixing coffee biochar with soil showed no statistically significant differences (p > 0.05) in total N (TN), Available P (Avail. P), Exchangeable K (Exch. K), Ca (Exch. Ca), Mg (Exch. Mg), Soil Organic Matter (SOM), pH, EC, Dissolved Organic Carbon (DOC), and Microbial Biomass Carbon (MBC). However, Soil Microbial Respiration (SMR) exhibited significant differences (p > 0.05), with the highest release observed in the 7.5% of biochar treatment. The analysis of fundamental nutrient elements revealed that TN, Avail. P, and Exch. K increased with increasing biochar levels, while Exch. Ca and Mg decreased. SOM and DOC increased, but MBC decreased with increasing biochar application. The addition of coffee biochar led to a reduction in fungal populations, with a maximum reduction of 68% in the 5% biochar treatment. However, it also increased the presence of microbes capable of producing cellulase enzymes for cellulose degradation and microbes capable of decomposing the substrate. In summary, while coffee biochar did not significantly affect most soil properties, it impacted microbial populations, reducing fungi but increasing beneficial microbes for decomposition and cellulose degradation.

Keywords: Agricultural waste, coffee biochar, microbial populations, soil properties

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

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Effect of clonal integration on drought and waterlogging response in *Urochloa humidicola*

MILDRED JULIETH MAYORGA, JUAN ANDRÉS CARDOSO The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

Clonal integration allows for the sharing of resources such as water, nutrients, and photosynthates among individual subunits of clonal plants, promoting adaptation to diverse environmental and ecological conditions. In livestock production systems, a key aspect in adapting to climate change is the use of forage materials tolerant to abiotic stresses such as water deficit and waterlogging. The accession of Urochloa humidicola CIAT 679 (cv. Tully) is a promising forage due to its good adaptation to acidic soils with low fertility, drought, and waterlogging. It also has a high biological nitrification inhibition capacity and efficient propagation through stolons, a reproductive system that allows for the maintenance of clonal integration among shoots of different generations. This study aimed to evaluate whether clonal integration is one of the strategies that confers tolerance to drought and waterlogging in CIAT 679. The treatments consisted of interactions between three stress conditions applied to the recipient clone: drought, control (no stress), and waterlogging, with two conditions of clonal integration: with integration and without integration (cutting between donor plant and recipient plant). Stomatal conductance, transpiration, SPAD index, relative water content (RWC), biomass distribution, and non-structural carbohydrates (NSC) were evaluated in the recipient plants. Stomatal conductance, transpiration, SPAD index, RWC, and NSC were lower in drought and waterlogging treatments that did not have clonal integration, with drought without integration being the most affected treatment. Root biomass was lower in drought treatments with and without clonal interaction, as well as in the waterlogging treatment with integration. This treatment also presented the lowest Root: Shoot ratio. The results suggest that clonal integration contributes to tolerance to waterlogging and drought stress in CIAT 679 plants, possibly through photosynthate translocation.

Keywords: Abiotic stress, CIAT 679, clonal plants, translocation

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

Investigation on leaf temperature and water use of Tatsoi cultivation under light and water stress

DIAH AJENG SETIAWATI^{1,2}, LILIK SUTIARSO², NGADISIH², MURTININGRUM² ¹Universitas Mataram, Dept. of Agricultural Engineering, Indonesia ²Universitas Gadjah Mada, Dept. of Agricultural and Biosystems Engineering, Indonesia

The research investigates the leaf canopy temperature (Tc) and water use efficiency (WUE) of Brassica rapa subsp. narinosa (Tatsoi plant) grown using the Nutrient Film Technique (NFT) hydroponic system under light and water stress conditions under controlled environmental conditions. Tatsoi plants, ten days post-sowing, were subjected to three shading treatments, i.e., full sunlight (A, 0% shading), moderate shade (B, 90% shading), and heavy shade (C, 99% shading), and three watering frequencies (24, 12, and 6 hours) within a greenhouse setting. The nutrient solution used was a balanced AB Mix, ensuring adequate mineral availability for plant growth. The experiment, conducted during the dry season over 28 days after plantation (DAP), revealed that Tatsoi's leaf temperature could be significantly moderated through evaporative cooling, particularly under total sunlight exposure. The highest difference between leaf and air temperature (Tc-Ta) in shading treatments (B & C) was found to be reduced by 45.94 % and 27.9 %, respectively. However, the imposition of shade and reduced watering frequency led to a marked decline in WUE, with the most severe reduction observed under the heaviest shading and least frequent watering conditions. The reduction percentage of WUE was more than 90% for moderate and heavy shading (B & C) treatment at each watering duration, compared with the full sunlight and 24-hour watering duration (A24). These findings underscore the resilience of Tatsoi to water stress under full sunlight, with only a minimum impact on WUE, contrasting with the substantial decrease in WUE associated with increased shading. The study's outcomes contribute to the broader understanding of plant physiological adaptations to environmental stressors, with implications for optimising cultivation practices in hydroponic systems, especially in tropical regions.

Keywords: Hydroponics, leaf temperature, light and water stress, Tatsoi plant, water use efficiency

Contact Address: Ngadisih, Universitas Gadjah Mada, Dept. of Agricultural and Biosystems Engineering, Jl. Flora No. 1 Bulaksumur, Depok, Sleman, 55281 Yogyakarta, Indonesia, e-mail: ngadisih@ugm.ac.id

Hydroponic screening for salinity tolerance in quinoa (*Chenopodium quinoa*): Physiological mechanisms

Anna Tabea Mengen, Caroline Blecker, Sandra Schmöckel University of Hohenheim, Physiology of Yield Stability, Germany

Salinisation of agricultural land poses a significant threat to global food security. In arid regions, where agriculture relies on irrigation, increasing salinity particularly impairs production. Quinoa (Chenopodium quinoa) is a drought and salt-tolerant crop from the Andes, which is known for providing highly nutritious seeds. It naturally exhibits a broad genetic diversity and is adapted to various marginal environments. Therefore, it is a perfect a candidate to sustainably diversify cropping systems in saline and arid regions, to make them more resilient. Consequently, indentifying guinoa accessions adapted to salinity and elucidating the respective tolerance mechanisms is important to enable quinoa breeding. This study aimed to screen 70 quinoa accessions for their salinity tolerance and investigate the underlying physiological mechanisms. In a randomised complete block design with six replications, plants were grown in a hydroponic system for 20 days until reaching six-leaf stage. They were then subjected to a 200 mM NaCl treatment for seven days. To assess physiological adaptions to salinity, leaf greenness, chlorophyll fluorescence and stomatal conductance were assessed one day before harvest. After harvest, biomass of roots and shoots, water content, osmolality and chlorophyll content of leaves were assessed. Furthermore, the content of Na⁺ and K+ ions in roots and shoots was assessed. As a measure for salt tolerance, a salt tolerance index was calculated based on the retention of biomass under salinity, between control and treatment group. The quinoa accessions screened differed in their salinity tolerance. Salinity tolerance was found to be related to various physiological parameters, such as ion content, depending on the accession. The results lay a foundation for further investigation of the underlying molecular mechanisms of salinity tolerance in quinoa and may also serve as a basis for investigating the efficiency of phenotyping in hydroponic systems for selection purposes.

Keywords: Hydroponics, quinoa, salt tolerance, soil salinity

Contact Address: Anna Tabea Mengen, University of Hohenheim, Physiology of Yield Stability, Otto-Sander-Str.5, 70599 Stuttgart, Germany, e-mail: tabea.mengen@uni-hohenheim.de

Effects of root zone temperature on nutrient depletion dynamics and growth performance of hydroponically grown tomato

SUSANNE WERNER, THERESA DETERING, FOLKARD ASCH University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

A potential strategy to mitigate climate change induced water scarcity is greenhouse based hydroponic cultivation of crops. One important factor affecting the growth of hydroponically cultivated plants is the root zone temperature (RZT). Earlier studies have shown, that approximately 25 °C constitutes the ideal RZT for tomato (*Solanum lycopersicum*). However, controlling temperature and humidity (VPD) in greenhouses, particularly during the hot months of the year, is difficult, and often results in RZTs higher than optimal. Here, we report on effects of increased RZT under humid and dry air conditions on growth and nutrient uptake of tomatoes.

Under two vapour pressure deficit (VPD) environments, tomato variety "Saluoso" was grown in deep-water hydroponics in a greenhouse experiment. The plants were subjected to contrasting RZT conditions, with temperatures of 24°C and 28°C respectively, during the day. Five destructive samplings were conducted at five-day intervals. For each sampling, fresh and dry fractionated biomass (leaves, stems, roots), total leaf area, plant height, and the Soil Plant Analysis Development (SPAD) were determined. Furthermore, a quantitative analysis of macro- and micronutrient uptake from the nutrient solution was conducted.

Preliminary results suggest that there are no statistically significant differences in total plant biomass production between the two RZT, or VPD. Nutrient solution analysis indicates that while there are no differences between the RZT treatments, combining low VPD with high RZT leads to earlier nitrogen depletion than other combinations. Regardless of RZT, high VPD led to increased leaf area with wider leaves in the later stages. The combination of high RZT and low VPD resulted in the narrowest leaves. The poster will discuss these effects on morphology with regard to nutrient uptake and distribution as affected by RTZ and VPD.

Keywords: Deep water hydroponic, growth, nutrient depletion, root zone temperatur, tomato, vapour pressure deficit

Contact Address: Susanne Werner, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), 70593 Stuttgart, Germany, e-mail: susanne.werner@uni-hohenheim.de

Mitigating drought stress in Arabica coffee seedlings through soil stabilisation with biochar derived from highland agricultural waste

Sasiprapa Kullachonphuri¹, Phonlawat Soilueang¹, Piyaphad Ninlaphong¹, Wiriya Sanjunthong², Yupa Chromkaew¹, Nipon Mawan², Wanwisa Pansak³, Nuttapon Khongdee²

¹*Chiang Mai University, Dept. of Plant and Soil Science, Thailand* ²*Chiang Mai University, Dept. of Highland Agric. and Natural Resources, Thailand* ³*Mahidol University, Fac. of Environment and Resource Studies, Thailand*

The application of biochar has been demonstrated to enhance soil properties, promote plant growth and productivity, and mitigate drought stress by increasing soil water holding capacity (WHC) through the alteration of soil physicochemical characteristics. However, the efficacy of biochar is variable and contingent upon factors such as feedstock source, pyrolysis temperature, and application rate. Therefore, this study aimed at investigating the effect of applying different doses of biochar as a soil amendment on Arabica coffee seedling under various soil WHC conditions. The experiment was conducted in a greenhouse located in Chiang Mai University, utilising corncob biochar at 4 doses (0, 1, 2.5, and 5% of soil weight) and 4 water irrigation conditions (100%, 60%, 40%, and 20% of WHC). Biochar derived from corncob was characterised by Field Emission Scanning Electron Microscope (FE-SEM). The basic physical and chemical characteristics of the soil and biochar were assessed. Growth and development of coffee seedlings were monthly measured. Plant responses were assessed through measurements of electrolyte leakage, relative water content, proline content, and total soluble sugar content. The results showed that biochar application contributed positively to growth and development of coffee seedlings (p < 0.05). No differences (p > 0.05) were observed between 100 % and 60 % WHC treatments, whereas the 40 % and 20 % WHC treatments with 2.5 % biochar exhibited the lowest levels of electrolyte leakage. The relative water content analysis revealed that 20% WHC with 5% biochar had the lowest value (26.57%). The proline content was highest in 20 % WHC with 0 % biochar (43.73 mM g^{-1} FW). In contrast, the total soluble sugar content was generally the highest under 100 % WHC with 0 % biochar (192.66 mg g^{-1} FW). It can be concluded that biochar derived from highland agricultural waste has the potential to mitigate the negative impacts of drought stress on Arabica coffee seedlings.

Keywords: Arabica coffee, biochar, drought stress, highland agriculture

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

Leaf pigment composition in wheat (*Triticum aestivum* L.) exposed to water deficit and heat stress

Geckem Dambo¹, Alejandro Pieters¹, Matthew Reynolds², Folkard Asch¹

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

²CIMMYT, Physiology and Remote Sensing, Mexico

Photoprotective pigments play a significant role in preventing negative effects of excessive light absorption on plant metabolism by preventing oxidative stress. Climate change-driven episodes of water deficit and heat spells would exacerbate such negative effects of excess light. However, information on the response of pigments composition in wheat leaves to abiotic stresses is scarce. We investigated the carotenoid and chlorophyll (Chl) composition at heading stage in flag leaves of sixteen elite spring wheat genotypes alongside with reflectance spectra measured by a canopy-level portable spectroradiometer. Field trials were carried out in Cd. Obregón, Mexico during two consecutive seasons (2021/2022 and 2022/2023) comprising three environments, namely Water Deficit (WD), Heat Stress (HS), and Well-Watered (WW) conditions. WD was irrigated only twice during the growing season, whereas WW was irrigated throughout at regular intervals. HS was achieved by adjusting the sowing date from December (WW and WD) to late February 2022 and 2023, management was as in WW. Carotenoids and Chls were determined by HPLC and spectrophotometry, respectively. WD and HS significantly affected transpiration rate, stomatal conductance, quantum yield of photosystem II, pigment related reflectance indices, and pigment composition. Genotypic differences were detected in pigment composition, SPAD values, transpiration, and stomatal conductance but not in reflectance indices. Carotenoids increased and Chl decreased under WD and HS, indicating activation of defensive mechanisms against stress such as non-photochemical quenching. To summarise the response of the genotypes and to identify key parameters associated to the response, a principal component analysis (PCA) was carried out. PCA segregated the three environments. PCA1 and PCA2 explained >80% of total variation. Yield and plant performance variables were highly and negatively correlated to PC1, whereas carotenoids concentrations were highly but positively correlated with PC1. WD and HS were associated to high scores on PC1, and WW was associated to negative scores on PC1. Our results suggest that photoprotective mechanisms related to carotenoid composition are activated by drought and heat stress in wheat. Hyperspectral reflectance using pigment related indices could not detect genotypic differences in pigment composition. However, genotypic differences could be identified through laboratory analyses, which is promising for selection purposes.

Keywords: Chlorophyll, drought, heat, photoprotection, photosystem II, pigments, stomatal conductance

Contact Address: Geckem Dambo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 13, 70599 Stuttgart, Germany, e-mail: geckem.dambo@uni-hohenheim.de

Unraveling heat tolerance in bread wheat (*Triticum aestivum* L.) using physiology and proteomics approaches

Agyeya Pratap¹, Nicolas Taylor², Madan Pal³, Viswanathan Chinnusamy³, Kadambot Siddique⁴

¹The University of Western Australia, School of Agriculture and Environment, Australia ²The University of Western Australia, Australian Plant Phenomics Network, Australia ³Indian Agricultural Research Institute, Division of Plant Physiology, India ⁴The University of Western Australia, The UWA Institute of Agriculture, Australia

Heat stress significantly impacts global bread wheat productivity. Our study aimed to identify underlying mechanisms of heat tolerance in wheat flag leaves and spike tissues. We compared physiology, yield, and protein abundance changes of wheat genotypes with contrasting heat tolerance (two tolerant [RAJ3765 and HD2932] and two susceptible [HD2329 and HD2733]) under short- and long-term heat stress (32°C) at ear peep. This experiment revealed that heat tolerant genotypes maintained grain yield under short-term heat exposure by maintaining photosynthesis, membrane stability, chlorophyll content, pollen viability, and redox homeostasis. Heat stress during ear peep reduced grain number, above-ground biomass, harvest index less in heattolerant than -susceptible genotypes while increased thousand grain weight and grain protein content, with significant genotype x treatment interactions. Notably, long-term heat stress reduced thousand grain weight more in heatsusceptible than -tolerant genotypes. We identified 31 and 60 changes in protein abundances in flag leaves and spike tissues, respectively. Key pathways in flag leaves included photosynthesis, RNA processing, heat shock proteins, redox homeostasis, carbohydrate metabolism, chromatin organisation, and protein breakdown, translation, and translocation. In spikes, prominent pathways included carbohydrate, lipid, and secondary metabolism, cell wall and chromatin organisation, redox homeostasis, membrane transport, methylation, protein folding, breakdown and translocation, RNA processing, lipid transfer, cell morphogenesis, heat shock proteins, and reproduction. Co-expression analysis revealed proteins correlated with important agronomic

traits. These proteins provided insights into mechanisms of heat tolerance associated wheat physiology and yield.

Keywords: Heat-stress, physiology, protein abundance, protein biomarkers, tolerance, wheat

Contact Address: Agyeya Pratap, The University of Western Australia, School of Agriculture and Environment, M082 35 Stirling Highway Crawley, 6009 Perth, Australia, e-mail: agyeya.pratap@research.uwa.edu.au

Salinity impacts on agriculture in sub-Saharan Africa – State of the art and call for action

Janina Smaoui 1 , Pim van Tongeren 1 , Katarzyna Negacz 1 , Jakob Herrmann 2

¹*Vrije Universiteit Amsterdam (VU), Inst. for Environmental Studies (IVM), The Netherlands* ²*Weltweit – Association for the Promotion of Local Initiatives e.V., Germany*

Soil and groundwater salinisation is a major challenge for agriculture and a pervasive problem throughout sub-Saharan Africa (SSA). Exacerbated by climate change, salinisation has profound impacts on the region's environment, economy, and people. However, reported data on the extent and impacts of salinity in SSA remains fragmentary. Recent studies conducted at the Vrije Universiteit Amsterdam (VU) and international expert networks such as the International Network of Salt-affected Soils (INSAS) worked towards systematising the available information and identifying knowledge gaps and action needs, principally through desk research along with key informant questionnaires and interviews. We present key outcomes of these research efforts, focusing on: (i) geographic extent of salinity along with classifications across countries, (ii) economic, environmental and social impacts of salinity, and (iii) the governance of salinity through international initiatives and policies. Estimates of salt-affected soils in sub-Saharan Africa range widely, from 19 to 161 million hectares, highlighting inconsistencies in research and classification methods. The level of information on salinity varies starkly between countries. While coastal areas are well studied, inland salinity also requires attention. More research is therefore needed, especially in arid and semi-arid regions. Furthermore, inconsistencies in salinity classification conventions between countries hinder supra-national comparisons and data alignment. Salinity has profound economic, environmental, and social impacts on affected countries, leading to significant crop yield losses and reduction of agricultural land, affecting livelihoods and food security. While international cooperation exists, the number of initiatives varies from country to country and focuses mainly on knowledge sharing and pilot projects. However, stronger commitments to funding, standards and long-term strategies are crucial for effective adaptation. Direct policies on salinity are rare, but they're often integrated into broader policies on soil, water, biodiversity and land degradation. The case study of salinity impacts on rice production systems in Eastern Africa is presented as an illustrative example, highlighting the prospects and challenges for supra-national efforts towards a conclusive understanding and management of the salinity problem in SSA. Our presentation intends to raise awareness and provide impulses for strengthening salinity research and action in SSA.

Keywords: Agricultural policy, climate change adaptation, food security, governance, groundwater salinity, land degradation, rice production, saline agriculture, salinity classification, salt-affected soils, soil salinity

Contact Address: Janina Smaoui, Vrije Universiteit Amsterdam (VU), Inst. for Environmental Studies (IVM), Amsterdam, The Netherlands, e-mail: j.smaoui@vu.nl

The effect of potassium fertiliser on the physiological responses of field-grown sweetpotato to salinity

Jane Cypriyana Pedinedi Jerald¹, Johanna Volk¹, Dhruv Patel¹, Maria Isabel Andrade², Folkard Asch¹

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

²International Potato Center, Flagship 2 - Adapted Productive Varieties and Quality Seed, Mozambique

Salinity is a growing constraint for agriculture by limiting both the area available for crop production and its efficient use. High concentrations of sodium chloride in the soil solution, can affect crop growth and yield through the competition of sodium (Na⁺) with potassium (K⁺) in plant uptake and translocation, resulting in absolute or relative potassium deficiencies in plant tissues. As potassium nutrition in plants is associated with key processes such as photosynthesis, enzyme activation, and phloem loading, salinity-induced K deficiencies may result in reductions in growth and ultimately yield. Sweetpotato varieties maintaining potassium acquisition, retention and a favourable leaf K⁺/Na⁺ ratio under salinity have been shown to suffer relatively small salt stress-induced reductions in biomass. Thus, increasing the availability of potassium in the soil may be a potential management strategy to improve the K⁺/Na⁺ ratio via the increased uptake of K⁺. However, little is known to date on K⁺ uptake and distribution as well as the effect of adding potassium fertiliser to sweetpotato, under saline field conditions.

This study tested two sweetpotato varieties (CIP 440004 and Huambachero) grown under saline and non-saline drip irrigation and supplied with potassium sulfate at two different levels: 33 kg ha⁻¹ and 66 kg ha⁻¹ in a field trial at the CIP research station in Maputo, Mozambique. Destructive samples were taken every 10 days to observe the changes in dry matter content of various plant parts at different growth stages. Sodium, chloride, and potassium concentrations and contents were determined to track salt uptake and distribution in different plant parts within the varieties.

The poster will discuss the development of a potassium fertiliser strategy to improve salinity tolerance and the yield of sweetpotato as a management strategy for marginal lands.

Keywords: Physiology, potassium fertiliser, salinity stress, sweet potato

Contact Address: Jane Cypriyana Pedinedi Jerald, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Birkheckenstr. 78c, 70599 Stuttgart, Germany, e-mail: janecypriyana.pedinedijerald@uni-hohenheim.de

Cultivar-specific responses to salinity: Investigating growth and ion distribution dynamics in *Solanum lycopersicum* under variable VPD conditions

HEMANTH KUMAR PUPPALA, FOLKARD ASCH, JÖRN GERMER University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Root zone salinity and atmospheric moisture demand significantly impact crop growth and yield. For adapting crop production to climate change, understanding the interaction between these factors helps develop resilient agricultural practices critical for sustaining food security.

Two varieties of *Solanum lycopersicum* (cv's Saluoso, Sweeterno) were grown hydroponically under high (3.1 kPa) and low (0.7 kPa) VPD at four levels of root zone salinity (RZS) namely 0, 20, 40 and 80 mM NaCl. Leaf area, evapotranspiration, plant height, leaf number, and stem diameter were recorded. Dry weights were determined from all plants partitioned into leaf blades, petioles, structural parts (petiolule and rachis), stems, and roots, and ion distribution (Na⁺, Cl⁻ and K+) from all partitioned plant parts were analysed.

Under high VPD conditions, RZS significantly reduced biomass by 38 % and 95 % in Saluoso and 32 % and 87 % in Sweeterno at 40 mM and 80 mM, respectively. In contrast, RZS of 20 mM and 40 mM increased biomass by 10 % and 32 % in Saluoso and Sweeterno respectively, under low VPD, whereas under 80 mM RZS under low VPD similar results were observed as under high VPD conditions. Sweeterno consistently outperformed Saluoso regardless of salinity or VPD treatment. High VPD had a significantly positive effect on dry weight and leaf area particularly at 0 mM RZS. However, this effect weakened with increasing salinity, and no significant difference was observed at 80 mM RZS.

The relationship between ion uptake and distribution and the positive effects of high VPD on biomass formation and leaf area will be discussed.

Keywords: Dry weight, hydroponics, leaf area, productivity, salinity, tomato, vapor pressure deficit (VPD)

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: hemanth.puppala@uni-hohenheim.de

Between eustress and distress: Tracing hormesis of salinity in a sweetpotato clonal pool

Johanna Volk¹, Dhruv Patel¹, Jane Cypriyana¹, Maria Isabel Andrade², Folkard Asch¹

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

²International Potato Center, Flagship 2 - Adapted Productive Varieties and Quality Seed, Mozambique

All biotic and abiotic factors can act as stressors. It is the strength of the factor and the duration of its action that determine whether there is stimulating eustress or destructive distress. One of the most damaging abiotic stresses affecting crop production is soil salinity with its disturbing effects on physiological processes in plants. In contrast, salinity at mild-to-moderate levels has been shown to positively affect biomass accumulation and yield. In sweetpotato, such positive effects of salinity are observable in published data. However, they are not being discussed in a dose-dependent context due to the focus on distress and the tolerance to it. Hormesis, here understood as a biphasic dose-response with a low dose stimulation and a high dose inhibitory effect, is under research when it comes to varietal selection for low stress environments. In order to separate varieties along the hormesis spectrum from eustress to distress, a large number of genotypes need to be tested. We explored the performance of 30 sweetpotato varieties under saline and non-saline drip irrigation at the CIP research station in Maputo, Mozambique in two consecutive dry seasons. Yield components and growth indicators including tuberous root number and weight, vine fresh weight and dry matter were determined at maturity. Additionally, tubers were analysed for beta-carotene, iron, zinc, starch, protein, and sugar content. Salinity effects were compared to the clonal pools' fresh water baseline and varieties clustered into groups according to the salinity impact. In the final analysis, we plan to link the clusters to shared traits. Discriminating salinity effects on individual genotypes as indicative for the position along the hormesis spectrum allows targeted selection of genotypes for stress-specific environments. This can provide a salinity management option which not only allows genotypes to tolerate saline conditions but, by making productive use of them, mitigating negative effects of degraded soils on crop production.

Keywords: Hormesis, salinity, 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

Agronomic and remote sensing-based assessment of paddy rice responses to salinity stress in Andalusia, Spain

Annkathrin Rosenbaum¹, Quintana-Molina, José Rodolfo², Mathias Becker³, Shyam Pariyar³, Gregorio Egea¹

¹TEPRO Consultores Agrícolas SL, RDI, Spain

²Spanish Council of Science, Inst. of Sustainable Agriculture (IAS-CSIC), Spain

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

The primary irrigation source of lowland rice in Isla Mayor (Andalusia, Spain) is the Guadalquivir River. Decreasing precipitation and increasing temperatures favour the seawater intrusion into the river, ultimately resulting in high salinity concentrations in the irrigation water and rice fields. This influx of salt, particularly sodium, disrupts the potassium-sodium (K:Na) balance in rice plants, hindering growth and reducing yields. Consequently, water scarcity and salinity significantly impact the cultivated area, resulting in harvest losses at both individual plant and plot levels.

To investigate the effects of salinity on rice varieties, a field experiment was conducted during the 2022 growing season across three farms with varying salinity concentrations (low, medium, and high). Leaf samples were collected from each farm, with two replications per treatment, and analysed for potassium-sodium ratios using flame photometry. Concurrently, local farmers provided yield data, while satellite images from Google Earth Engine were utilised to calculate vegetation indices for trial plots. These indices were then compared with potassium-sodium ratios and final plot yields obtained from the field experiment.

During the vegetative growth stage, strong correlations were observed between vegetation indices and rice yield, particularly during the rapid vegetative growth phase. Notably, NDRE exhibited the highest correlation with salinity levels, while the EVI and SAVI indices demonstrated the best fit with rice yield. Additionally, dynamics of NDVI mirrored those of potassium-sodium ratios during rapid vegetative growth, highlighting its usefulness in identifying critical phases for yield prediction under salinity stress.

This study emphasises the potential of open-source remote sensing tools for making informed decisions regarding water allocation in rice cultivation under elevated salinity conditions. By understanding the relationship between vegetation indices, salinity levels, and crop yield, farmers can better manage water resources and mitigate the negative impacts of salinity on rice production.

Keywords: Google Earth Engine, *Oryza sativa*, plant growth, sodium toxicity, vegetation indices, yield

Contact Address: Annkathrin Rosenbaum, TEPRO Consultores Agrícolas SL, RDI, Avda. San Francisco Javier, 24, Edif. SEVILLA 1, 3ª planta, 41018 Sevilla, Spain, e-mail: anni@tepro.es

Does lettuce and pak choi benefit of intercropping with the halophyte glasswort?

Shikhar Acharya¹, Maria Fitzner^{1,2}, Monika Schreiner², Susanne Baldermann^{1,2}

¹University of Bayreuth, Germany

²Leibniz Inst. of Vegetable and Ornamental Crops (IGZ), Food4Future (F4F), Germany

Salt accumulation in the soil is increasing by approximately 10% annually e.g. due to high surface evaporation, weathering of native rocks, and poor agricultural practices. High salinity imposes osmotic stress and ion toxicity which negatively affects the nutritional quality and has a negative impact on the economic value. This research aimed to study if the quality of salt-sensitive lettuce (Lactuca sativa) and pak choi (Brassica rapa sp. chinensis) could be improved through intercropping with salt-tolerant glasswort (Salicornia europaea) in saline conditions. The experiment was conducted for 5 weeks in a greenhouse under three treatment conditions: Control (freshwater), 50 mM NaCl, and 100 mM NaCl. The design consisted of 9 individual plants in monoculture and a combination of 3 lettuce, 3 pak choi, and 3 glasswort plants in an intercropping system. Plants were analysed for ions and selected bioactive compounds using ion chromatography and HPLC-DAD, respectively. Results were compared using Oneway ANOVA ($p \le 0.05$). Plants' survival rates showed beneficial intercropping effects only for lettuce at 50 mM salt treatment; so pak choi and 100 mM salt treatment were not considered for further analysis. The β -carotene content in lettuce grown in intercropping at 50 mM salt treatment $(5.41 \pm 0.58 \text{ mg}/100 \text{ g dw})$ was significantly higher compared to the lettuce grown in monoculture at 50 mM salt treatment (2.05 + 0.26)mg/100 g dw). Similarly, lutein content in lettuce at 50 mM (6.19 \pm 0.89 mg/100 g dw) was significantly higher than its monoculture counterpart $(1.49 \pm 0.27 \text{ mg}/100 \text{ g dw})$. Both chlorophyll a and b content at 50 mM salt treatment were found to be significantly higher in lettuce grown in intercropping ($166.70 \pm 10.01 \text{ mg}/100 \text{ g}$ dw and 45.45 ± 3.11 mg/100 g dw) than its monoculture counterpart (58.87 + 4.43 mg/100 g dw and 13.27 \pm 1.25 mg/100 g dw). In contrast, chloride concentration in intercropping lettuce at $50 \text{ mM} (107.1 \text{ 8} \pm 1.94 \text{ mg s}^{-1} \text{ dw})$ was significantly lower than its monoculture counterpart (117.80 \pm 3.76 mg g⁻¹ dw). These findings suggest that lettuce benefits from growing in an intercropping system with glasswort (up to 50 mM salinity) and could contribute to developing cultivation strategies for saline soils, promoting sustainable resource management and food security.

Keywords: Lettuce, pigments, polyculture, salicornia, saline agriculture

Contact Address: Shikhar Acharya, University of Bayreuth, Bayreuth, Germany, e-mail: ckharacharya@gmail.com

Impact of environmental stress on bioactive compounds in shiitake mushrooms

Barbora Motýlová, Klára Urbanová, Jan Banout

Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Sustainable Technologies, Czech Republic

Shiitake (*Lentinula edodes*), a very popular edible mushroom from East Asia is appreciated due to its nutritional value, rich aroma, specific taste, and its beneficial effects on human health. Despite numerous shiitake-focused studies are exploring differences in the biochemical composition according to strains or substrates they grow on, there is a notable absence of scientific literature addressing the influence of environmental conditions and if so, research emphasises correlations with yield, neglecting the broader implications on bioactive compound production.

Harsh environmental conditions influence the production of diverse bioactive compounds and also induce creation of so-called secondary metabolites which help mushrooms to adapt and survive in changing ambient conditions. These compounds not only enhance mushroom resilience but they also have nutritional, organoleptic, or medicinal value for humans. Key secondary metabolites in shiitake include polyacetylenes (having antimicrobial activities), sulfurous compounds (responsible for specific shiitake aroma), lovastatin (lowering blood cholesterol and preventing cardiovascular diseases), eritadenine (cholesterol-reducing compound), or ergosterol (precursor of vitamin D2).

In this study blocks of the substrate with shiitake mushrooms were cultivated in laboratory conditions. Some blocks were subjected to abiotic environmental stresses – heat, cold, and drought – in a controlled climate chamber. Harvested mushrooms were dried and ground. The headspace solid-phase microextraction gas chromatography mass spectrometry (HS-SPME-GC-MS) was used to analyse volatile compounds. Several compounds, including carbon disulfide, 3-octanone, hexanal, 1,2,4-Trithiolane, and others, were analysed. Significant differences were observed in the levels of carbon disulfide, while hexanal showed minimal variation. Also, the amount of ergosterol in treated samples was examined.

This study contributes to better understanding of how environmental factors influence the biochemistry of shiitake mushrooms and may help with optimising of cultivation conditions in order to maximise the production of desirable compounds improving its sensory and nutritional properties. Moreover, increased presence of ergosterol has a great potential for improving not only vegans and vegetarians diets, where vitamin D supplementation is needed due to its scarcity in plant-based foods.

Keywords: Environmental stress, *Lentinula edodes*, secondary metabolites, volatile compounds

Contact Address: Barbora Motýlová, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences - Dept. of Sustainable Technologies, Kamycka 129 Suchdol, 18200 Prague, Czech Republic, e-mail: barbora.motylova@gmail.com

Assessing physiological responses in different leaf positions of wheat genotypes under water deficit

Prem Sagar Mathangi¹, Geckem Dambo¹, Alejandro Pieters¹, Matthew Reynolds², Folkard Asch¹

¹University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany ²CIMMYT, Physiology and Remote Sensing, Mexico

Heading and grain-filling are the most susceptible stages to water deficit. At these stages, the flag leaf is the most metabolically active leaf, providing the largest fraction of the carbohydrates needed for grain filling. However, lower leaves can also contribute to final yield through current photosynthesis and translocation of previously assimilated carbon. However, little is known about the physiological status of lower leaves and how it is affected by water deficit. This study investigates the physiological changes in both flag and third leaves of 24 elite genotypes from CIMMYT's Best PT panel grown in the field under well-watered and water deficit conditions. Trials were carried out in Cd. Obregón, Mexico, during the season 2023–2024. The water deficit treatment was irrigated at sowing, and the well-watered environment was irrigated at the sowing stage and every 15 days and later reduced to every 10 days during late grain filling. Transpiration rate, stomatal conductance, and quantum yield of photosystem II were measured at the booting, heading, and grain-filling stages using the LICOR LI-600 porometer, the SPAD 502 Plus was used to estimate chlorophyll concentration. Results showed differences in transpiration rates, stomatal conductance, and SPAD values at different leaf positions in water-stressed plants and irrigated plants. SPAD values, stomatal conductance, and transpiration rates were higher in irrigated than droughted plants. The quantum yield of photosystem II varied among the genotypes and leaf positions. A decline of quantum yield of PS II was observed under drought compared to irrigated conditions, possibly due to reduced photosynthetic rate. Flag leaves showed higher stomatal conductance, quantum yield, transpiration rates, and relative chlorophyll content than the third leaves. The SPAD values gradually increased as the growth stages progressed from heading to physiological maturity stage. However, the transpiration rates and stomatal conductance showed a decreasing trend at later growth stages. Further analysis will be performed to relate the physiological parameters presented here to plant biomass and grain yield.

Keywords: Canopy levels, climate change, physiology, stomatal conductance, transpiration, wheat

Contact Address: Prem Sagar Mathangi, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Fruwirthstraße 3, 70599 Stuttgart, Germany, e-mail: premsagar.mathangi@uni-hohenheim.de

Climate-smart strategies: Improving cotton resilience through superior leaf phenotyping

Hira Maryam, Zulfiqar Ali, Muhammad Abu Bakar Saddique

MNS University of Agriculture, Multan, Inst. of Plant Breeding and Biotechnology, Pakistan

Climate change and resource scarcity are the major challenging drivers to focus on developing climate-resilient crops. Under climate change, combating erratic temperature fluctuations is an arduous challenge. Cotton (*Gossupium hirsutum*) is an economically important oilseed crop for its textile fibre but the heat stress is a major constraint in lowering its yield by devastating crop at the early and terminal reproductive stages. Cotton is a major cash crop in Pakistan with 80% livelihood depending on agriculture. There is a dire need to mitigate environmental calamities by exploring innovative phenotyping strategies to develop climate-resilient cotton. The present study aimed to explore the early stress establishment and tolerance through superior leaf anatomical and physiological traits to sense stress signals. For this purpose, Relative cell injury of 50 cotton genotypes was measured at seedling stage resulted in categorisation of 20 contrasting genotypes with low RCI 14% as heat tolerant and heat sensitive between 70 to 100 RCI%. This coreset of 20 cotton genotypes were investigated under two temperature regimes: control and heat-stressed (>45°C) using a chamber) at different developmental stages. Leaf physiological traits including net photosynthesis, stomatal conductance, transpiration rate and photosynthetic water use efficiency and chloroplast showed significant differences in contrasting genotypes at seedling and reproductive stages. These traits were efficient in heat tolerant genotypes as compared to heat susceptible cotton genotypes. A biplot analysis indicated significant variation in yield related traits and fibre quality traits. Further, scanning electron microscopy (SEM) results indicated difference in leaf stomatal density and sizes of heat tolerant and heat sensitive genotypes, correlated efficient stomatal conductance with net photosynthesis rate under heat stress treatment. Moreover, the size and thickness of trichomes were high in heat tolerant genotypes as trichomes play diverse role in plant acclimation toward thermo-switches. The traits under study suggested that these are the efficient indicators in selecting heat tolerant genotypes. Utilizing these non-destructive trait study in breeding programmes has the potential to improve heat stress tolerance and overall plant performance. In future studies, these phenotypic plasticity parameters will promote cotton cultivation under harsh weather conditions that will uplift country economy and livelihood.

Keywords: Abiotic stress, anatomical structure, gossypium hirsutum, physiological parameters

Contact Address: Hira Maryam, MNS University of Agriculture, Multan, Institute of Plant Breeding and Biotechnology, MNS University of Agriculture, Old Shujabad Road, near PTV Station, 66000 Multan, Pakistan, e-mail: hira.maryam01@gmail.com

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Assessing the impact of farmers' indigenous seeds and seed conservation practices in Nakuru county Kenya

Lorenz Bachmann¹, Dominic Kimani², Julia Kamau², Johannes Kotschi¹, Dalmus Mitei², Daniel Wanjama²

¹Agrecol Association, Germany ²Seed Savers Network Association, Kenya

Farm-saved seed is existential for agriculture and nutrition in Kenya. For many crops families rely almost entirely on their own seed conservation for cultivation needs. Genetically, local cultivars are the result of generations of farmers' expert knowledge in plant selection. Seed supply and agrobiodiversity loss is a major threat for Kenya. To fight this problem, Seed Savers Network Kenya together with AGRECOL introduced a commons-based process of describing and documenting local varieties (open-source seeds) that is intended to help farmers seed supply and provide adequate protection against bio-piracy. Over a period of two years, farmers recorded their progress towards better seed security using a participatory impact monitoring tool (PIM). 200 Farmers in 13 villages were trained and a total of 132 farmers participated in PIM. To enhance income diversification and promoting biodiversity, 76 % of farmers increased the number of crops on their farm, 19% thereof to more than 21 crops per household. Furthermore, 30% of farmers began with the cultivation of drought tolerant crops. Fruit tree cultivation was taken up by 44 % of farmers. Seed production and working together in seed banks resulted in the fact that 75 % stated a significantly revived culture of seed sharing. The availability of seed could be improved for various local populations of beans, potato, black nightshade, and garden peas. The effects were marked strong for those farmers with lowest seed supply grade of less than one quarter of sowing needs. The number of farmers in this poorest category dropped from 55% to 27% while farmers with excellent seed supply rose from 3% to 17%. Progress could also be achieved on better seed storage and here the percentage of farmers in the poorest grade fell from 55% to 14%.

These various changes combined with new agroecological practices and water saving technologies practices let to the fact that 91 % of farmers reached better food security. Describing their local varieties 10 farmer groups managed to characterise and distinguish a total of 69 different varieties from 8 species. Being able to distinguish local varieties according to scientific procedures filled farmers with pride and enthusiasm.

Keywords: Agrobiodiversity, farmers' varieties, indigenous seed

Contact Address: Lorenz Bachmann, Agrecol Association, Breiteweg 1, 35415 Pohlheim, Germany, e-mail: l.bachmann@gmx.de

Exploring the population structure and genetic diversity of *Moringa oleifera* using DArTSEQ derived SNP markers

JANTOR NDALO¹, PRASAD HENDRE¹, ALICE MUCHUGI¹, STEVEN RUNO² ¹The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Trees Genetic resources and Biodiversity, Kenya

²Kenyatta University, Kenya

Moringa oleifera is a versatile tree native to the foothills of the Himalayas and now naturalized in the tropics. Moringa is nutritionally significant owing to its high nutrients and antioxidant content. Despite its increasing use as a fodder crop, wood fuel, medicine, an anticoagulant and a potential source of biofuel, the genetic diversity of Moringa across the tropics remains under investigated. In this study, we employed SNP markers derived from DArTSEQ technology to investigate the genetic makeup of Moringa oleifera. Genomic DNA was extracted from 95 accessions from 19 provenances collected from Africa, Caribbean and South East Asia. 3968 SNP markers were identified using DArTSEQ technology, which combines complexity reduction methods with next-generation sequencing. These were culled to a final set of 1913 informative markers that were then used for population structure and genetic diversity analysis. Unweighted neighbour joining phylogeny and principal coordinate analysis revealed four distinct clusters related to the geographic origin: Caribbean (Haiti/Jamaica) and East African (Kenya/Tanzania) were identified to be a subset of the West African (Mali/Ghana) population while the South African (Malawi) segregated distinctly. Philippines samples clustered separately and farthest as expected. Analysis of molecular variance revealed high gene flow within populations (77%) compared to among populations (23%). Bayesian modelling in structure with best k being two still distinctly segregated the South African (Malawi) population from the other African regions suggesting a distinct introduction. The significant admixture of individuals noted in structure is typical of unnatural introductions possibly through human mediated events. This study highlights the power of SNP markers from DArTSEQ technology in elucidating the genetic structure and molecular diversity of Moringa oleifera. The findings contribute to our understanding of the genetic resources of this important plant species and have implications for germplasm collection, improvement, conservation, utilisation strategies and policies. Further research utilising advanced genomic tools will enhance our knowledge of Moringa oleifera and support its sustainable utilisation for various applications.

Keywords: Diversity array technology, genetic structure

Contact Address: Jantor Ndalo, The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Trees Genetic resources and Biodiversity, 30677, 00100 Nairobi, Kenya, e-mail: j.ndalo@cifor-icraf.org

A simple algorithm outperforms a machine learning approach for quantifying spittlebug damage in tropical grasses

Andrés Felipe Ruiz, Paula Espitía, Juan Andrés Cardoso, Rosa Noemi Jauregui

The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

In the extensive livestock systems of tropical America, host-plant resistance has proven to be the most efficient strategy for integrated pest management in forage grasses (i.e., *Urochloa* hybrids and *Megathyrsus maximus*) to spittlebug (Hemiptera: Cercopidae) attack. Precise and efficient quantification of spittlebug damage is crucial for evaluation and selection of resistant and tolerant genotypes in the Urochloa spp. and M. maximus breeding programmes at CIAT. Traditional methods rely on visual inspection by experts, which is a time-consuming and resource-intensive process. Recent advancements in image processing offer the potential for automated high-throughput (HTP) analyses pipelines. The proposed pipeline involves image pre-processing (normalisation, feature enhancement, and plant segmentation) followed by a damage segmentation algorithm. Considering the large data volumes in breeding trials, where five replicates of 150 genotypes are assessed to spittlebug damage, often with limited availability of ground truth data, unsupervised learning approaches like clustering are preferred for damage segmentation. Furthermore, real-world image acquisition introduces challenges due to variability in lighting, noise, and lack of standardisation. The objective of this study was to compare a simple algorithm (Heckbert's median-cut colour quantisation) with the k-means unsupervised machine learning approach for quantification of plant damage (green/chlorotic leaf tissue) by spittlebugs using colour images. Our results showed that Heckbert's median-cut colour quantisation delivers similar results of quantification of plant damage to those obtained by K-means, yet, at a faster speed and less usage of CPU processing. We conclude that Heckbert's median-cut colour quantisation provides a computationally efficient and accurate solution for HTP spittlebug damage analysis of tropical forage grasses in CPU resource-constrained devices. This will facilitate the implementation of automated image analyses of spittlebug damage of tropical forage grasses for researchers working with old computers or mobile devices.

Keywords: Clustering algorithms, colour quantisation, damage segmentation, image processing, k-means, plant phenotyping, tropical forages

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

Farmer-led rice breeding of climate resilient rice

Maria Rowena Buena¹, Lucil Ortiz¹, Elizabeth Cruzada², Lorenz Bachmann³

¹MASIPAG, Philippines ²MASIPAG, Germany ³Agrecol Association, Germany

In many communities in the Philippines, farmers face increasing levels of climate related unpredictability aggravated by economic and political risks that further heighten farmers vulnerability risks. For the farmer organisation MASIPAG, resiliency is a long-term process that builds on the interdependence of technical, social, and political realities on the ground. Since 1988, Masipag has collected and maintained more than 1,000 old traditional rice varieties and 1,085 improved varieties have been bred by farmers and by staff of the Masipag back-up farms.

Among the farmer breeders Pepito B. Babasa (PBB) was one of the most popular rice breeders living near Lake Bato in Camarines Sur. The area has highly variable rainfall ranging from 1900 to 3800mm that is mainly caused by an average of 10 typhoons that cross the area annually. These storms cause strong levels of flooding with a high risk of total crop failure. Several of the PBBs varieties can cope with these exorbitant stresses. In his lifetime, Pepito Babasa has produced 33 farmer-bred lines and out of these he made more than 150 selections for a multitude of different needs based on the discussions within his farmer community and the wider Masipag network.

For example, one of his top varieties PBB 401 was found drought resistant in 3 provinces, and additionally lodging and pest resistant in another province outside his own farm. Other PBB lines were identified to be drought and saltwater tolerant, especially in Negros Occidental. Furthermore, Mr. Babasa was able to develop seed conservation techniques that allow farmers to have rice seeds available anytime. Consequently, farmers no longer need to worry about seed availability after typhoons, since more seed is available and also the system of Masipag backup farms helps to provide seed in case of case of extreme weather calamities.

Overall, the Masipag network identified a total of 114 local rice varieties with specific climate related resilience properties, thereof the following number or varieties are resilient to lodging and wind (39), flood tolerance (8), drought tolerance (33), pest and disease resistance (9) and salt water tolerance (3).

Keywords: Climate change, farmer-led rice breeding, resilience

Contact Address: Elizabeth Cruzada, MASIPAG, Breiteweg 1, 35415 Pohlheim, Germany, e-mail: bcruzada@gmail.com

The oilseed palm *Acrocomia*: Unlocking flowering patterns of various wild types from Brazil

Catherine Meyer 1, Claudio E.M. Campos 2, Thomas Hilger 1, Sérgio Motoike 3, Georg Cadisch 1

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

²Federal University of Viçosa, Dept. of Forestry, Brazil ³Federal Univerity of Viçosa, Dept. of Agronomy, Brazil

Acrocomia, an oilseed palm species endemic to the subhumid tropics of South and Central America, is feasible for sustainable vegetable oil production in areas where oil palm cultivation is limited. The wild populations of Acrocomia are morphologically diverse and their adaptation to a wide range of soil and climate conditions makes them important components of silvopastoral systems in Brazil. However, the knowledge of variations in flowering patterns is limited but crucial for a better understanding of mating opportunities and yield formation. These palms produce multiple inflorescences that flower sequentially from October to December. Since Acrocomia is protogynous, cross-pollination is dominant. Therefore, this study aimed to evaluate the flowering patterns, including the onset, peak, synchrony, and frequency of different Acrocomia wild types originating from various regions of Brazil. The study was carried out at the living germplasm collection BAG-Macaúba maintained by the University of Viçosa, Brazil, and located in Araponga, MG, Brazil. The flowering progress and frequency of six accessions (31 palms in total) were monitored from 2019 to 2021. Fruit set was assessed for the years 2019 and 2020. The statistical exploration of the flowering pattern was done using circular statistics, which accounts for the circular nature of phenological data. Circular statistics ensure proper representation of central tendency and avoid distortions (e.g. bias of calculated mean) near the turn of the year because they treat time as a circular scale, preventing January and December from being considered as separate endpoints, thereby reducing the impact of boundary effects on the data. Over three years, 382 inflorescences were documented, 120, 166, and 96 in 2019, 2020, and 2021, respectively. Flowering generally started in September and continued until the end of January, with the peak in the second half of November. The accessions varied strongly in their number of inflorescences and flowering onset, ranging from mid-September to mid-November. The individual palms of each accession showed high variability in their flowering frequency. Nevertheless, the flowering pattern of each accession remained similar between years. Through a redundancy analysis, solar radiation and rainfall were found to be the major impacting factors on flowering time.

Keywords: Brazil, circular statistics, oilseed palm *Acrocomia*, phenological flowering patterns, sustainable vegetable oil

Contact Address: Catherine Meyer, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstrasse 13, 70593 Stuttgart, Germany, e-mail: catherine.meyer@uni-hohenheim.de

Efficiency of thermotherapy and cryotherapy – virus elimination in *Ullucus tuberosus* Caldas

Maceo Milesi¹, Veronica Valencia², Rainer Vollmer², Maria Roman², Tiffany Calzada², Melody Amao², Bettina Heider²

¹International Potato Center, Agricultural Science, Switzerland ²International Potato Center (CIP), Genebank, Peru

Ullucus tuberosus Caldas, an Andean root and tuber crop, is the second most cultivated crop in the Andean region of South America. The crop plays a vital role in food security and is of great importance to the region. The morphological and genetic diversity of this vegetatively propagated crop is vast and holds significant potential for addressing future challenges. Therefore, preserving, storing, and making this diversity accessible is crucial. The genebank at the International Potato Centre conserves Ullucus; however, its distribution is restricted because the plants have not been cleared of viruses, and there are no established phytosanitary protocols to test plant health-a prerequisite for distributing in vitro plant material. Notably, secondary virus infection (arising from mother tubers) can result in yield losses of up to 38%. Additionally, since these plants are clonally propagated, it's essential to store living plant material to maintain their genetic diversity. This necessitates the complete elimination of viruses from the plant material as well before storage. In this study, we investigate the efficiency of two virus elimination methods thermotherapy with meristem culture and cryotherapy – on seven Ullucus accessions. Our study revealed that thermotherapy combined with meristem culture eliminates viruses at an efficiency rate of 84%, whereas cryotherapy achieves only 45% efficiency. Despite requiring substantial labour and resources, thermotherapy with meristem cultivation remains the most effective method for removing viruses from vegetatively propagated plant material. In the future, continuous assessment of new methods and techniques is important to identify and adopt more efficient techniques, particularly as not all crop species resist thermotherapy.

Keywords: Andean region, food security, genebank, *in vitro* plant material, meristem culture, phytosanitary protocol, root and tuber crop, vegetatively propagated crop, virus elimination

Contact Address: Maceo Milesi, International Potato Center, Agricultural Science, Bauenstrasse 3, 6010 Kriens, Switzerland, e-mail: milesim@student.ethz.ch

Lipidome-based genome-wide association analysis in pigmented rice sprouts revealed higher antioxidant and anti-cancer properties

Rhowell Jr. Tiozon¹, Erstelle Pasion-Uy¹, Saleh Alseekh², Alisdair Fernie², Nese Sreenivasulu¹

¹International Rice Research Institute, Philippines ²Max-Planck-Institute of Molecular Plant Physiology, Germany

The genetic wealth present in pigmented rice varieties offers abundant variation in different antioxidants to meet nutritional security targets among riceconsuming communities. Recently, germination has also gained much attention as a method to further enhance the dietary properties of rice. However, there is limited knowledge of the dynamic changes in the lipidome of rice during germination and the corresponding genes associated with the accumulating lipids.

In this study, we profiled the lipidome of diverse pigmented rice collections of germinated sprouts. Genome-wide association studies (GWAS), gene-set analysis, and targeted association analysis revealed 72 candidate genes involved in the regulation of these accumulating lipids in pigmented rice sprouts (PRS), with a particular emphasis on lipase-related genes. The selected GDSL esterase/lipase (GELP) genes contribute to enhanced antioxidant and anticancer activities. By identifying the relatively high PVE contributing top five genes [(LOC_Os02g40440, OsGELP40), (LOC_Os10g05088, OsGELP102), (LOC_Os10g30290, OsGELP107), (LOC_Os01g52230, OsACP1), and (LOC_-Os09g27210 - lecithin-cholesterol acyltransferase] we identified superior genome-wide identification of high-value marker-trait association (MTA) combinations GGTAAC/ ACAAGCTGGGCCC exhibiting higher antioxidant activity measured across three independent antioxidant methods (p < 0.05). The superior MTA combinations possess effective inhibitory activity against HCT116 colon cancer and A549 lung cancer cell lines with an average 1/IC50 of 0.03 and 0.02 $(mL/\mu g)$ compared to the inferior MTA combination (AATGACACAGCCGGGCCC), respectively. Evolutionary analysis revealed that GELP genes have been invoked by differential selection pressures experienced by Indica and Japonica subspecies. This study provides valuable insights into the potential health benefits of germination as a valuable dietary source of lipids for human health.

Keywords: Anticancer, antioxidant, gwas, lipid, pigmented rice

Contact Address: Rhowell Jr. Tiozon, International Rice Research Institute (IRRI), Consumerdriven Grain Quality and Nutrition Center, Pili Drive Ave up Los Banos Laguna, 4031 Laguna, Philippines, e-mail: r.tiozon@irri.org

Multi-omics unraveled genes and pathways responsible for the low glycemic index and high protein rice

Rhowell Jr. Tiozon¹, Erstelle Pasion-Uy¹, Alisdair Fernie², Nese Sreenivasulu¹

¹International Rice Research Institute (IRRI), Philippines ²Max-Planck-Institute of Molecular Plant Physiology, Germany

To address the growing incidences of increased diabetes and to meet the daily protein requirements, we developed low glycemic index (GI) rice varieties with a protein yield exceeding 14%. In the development of recombinant inbred lines using Samba Mahsuri and IR³6 amylose extender as parental lines, we identified quantitative trait loci (QTLs) and genes associated with low GI, high amylose content (AC), and high protein content (PC). By integrating genetic techniques with classification models, this comprehensive approach identified candidate genes on chromosome 2 (qGI2.1/qAC2.1 spanning the region from 18.62 Mb to 19.95 Mb), exerting influence on low GI and high amylose. Notably, the phenotypic variant with high value was associated with the recessive allele of the starch branching enzyme 2b (sbeIIb). The genome-edited sbeIIb line confirmed low GI phenotype in milled rice grains. Further, combinations of alleles from the highly significant SNPs from the targeted associations and epistatically interacting 2 genes showed ultra-low GI phenotypes with high amylose and high protein. Metabolomics analysis of rice with varying AC, PC, and GI revealed that the superior lines of high AC and PC, and low GI were preferentially enriched in glycolytic and amino acid metabolism, whereas the inferior lines of low AC and PC and high GI were enriched with fatty acid metabolism. The high amylose and high protein RIL (HAHP_101) were enriched in essential amino acids like lysine. Besides amino acids, pathway analysis unveiled phenolic compounds such as tricin, caffeoylquinic acid, feruloylglucoside, p-coumaroyglucoside, luteolin-6-glucoside, hydroxygallic acid derivative, caffeoyl hexoside, and sinapoyl glucoside were found to significantly accumulate in the low and ultra-low GI rice lines. Such lines may be highly relevant for food product development to address diabetes and malnutrition.

Keywords: Glycemic index, metabolomics, protein, QTLs, starch

Contact Address: Rhowell Jr. Tiozon, International Rice Research Institute (IRRI), Consumerdriven Grain Quality and Nutrition Center, Pili Drive Ave up Los Banos Laguna, 4031 Laguna, Philippines, e-mail: r.tiozon@irri.org

Rice and nutritional quality: Grain quality of highland rice genotypes cultivated in Jumla, Nepal

Shyam Pariyar¹, Nagendra Bastakoti², Shova Shrestha³, Mathias Becker¹

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

²Agriculture and Forest University (AFU), Dept. of Agricultural Economics and Agribusiness Management, Nepal

³Nepal Agriculture Research Council (NARC), National Soil Science Research Centre, Nepal

The cultivation of highland rice relies on cold-tolerant Oryza sativa japonica landrace, and is directly associated with an ample availability of water combined with low and often highly fluctuating temperatures and very high solar radiation depending on altitude, latitude, and topography. Particularly low (night) temperatures delay the phenological development of highland rice and increase spikelet sterility, affecting the production and productivity of landraces and resulting in relatively low grain yields as compared to the national average. Thus, food insecurity prevails in much of the highland regions, especially in Karnali, where food shortages shape the vulnerability of rural livelihood since decades. On the other hand, low temperatures combined with high UV radiation at high altitudes may enhance antioxidants and phenolic compounds in the grain, thus positively affecting grain quality. However, the morphological and nutritional quality may vary between rice genotypes and across altitudinal gradients. We collected grain samples at rice harvest of seven genotypes including three parental lines including local and improved cultivars grown at Agricultural Research Station, Bijayanagar, Jumla (2300 masl) and from other three altitudinal gradients, namely Tatopani (2200 masl), Sinja (2300 masl) and Chhumchaur (2900 masl) from farmers' field during the harvesting period. Grain morphological traits (grain weight, shape, size) was analysed using scanning electron microscope coupled with energy disperse X-ray (ESEM-EDX) and mineral composition of grain samples was analysed using Inductively Coupled Plasma – Optical Emission Spectroscopy (ICP-OES) in the lab at the University of Bonn. Larger grain was observed for improved genotypes Chandanath 1, Chandanath 3 and Lekali 1 than local cultivar Jumli Marshi, and the 1000 grain weight was higher for Chandanath 3 (31.3 g). Interestingly, mineral contents (Fe, Zn, P) was significantly higher in local cultivar Marshi, whereas Ca was found higher in Black rice. Our results suggest that local cultivar Marshi has superior mineral nutrients quality even though the grain morphology associated yield seems to be relatively low. Our study reports for the first time on the associated change trends in grain morphological and nutritional quality attributes across altitudinal gradients of Nepal.

Keywords: Agronomic traits, grain morphology, Karnali, Oryza sativa

Contact Address: Shyam Pariyar, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Karlrobert-kreiten Strasse 13, 53115 Bonn, Germany, e-mail: spariyar@uni-bonn.de

Extensibility of Guadeloupe collection of *alata* yam accessions reveal potential candidates for pounded yam production

Ayetigbo Oluwatoyin¹, Santiago Arufe-Vilas¹, Romain Domingo¹, Olivier Hubert², Sandrine Andypain², Komivi Dossa², Christian Mestres¹, Dominique Dufour¹

¹*French Agric. Res. Centre for International Development (CIRAD), France* ²*French Agric. Res. Centre for International Development (CIRAD), Guadeloupe*

This study aimed to provide information on the diversity of textural properties of the CIRAD/INRAe D. alata collection, which is one of the most diverse globally. A collection of 48 accessions of *alata* yam was analysed in the Antilles, Guadeloupe, in order to identify accessions that are potential candidates suitable as parents for transfer to Africa for the purpose of breeding for pounded yam production. Among the key sensory textural attributes preferred by consumers of pounded yam, the stretchability is more important, and it can be measured instrumentally as extensibility. Pounded yam was prepared by a standard procedure from known mass of fresh yams with known dry matter. Fresh yam was steamed for 20 min and pounded in a machine for 1-3 min with the amount of warm water necessary to adjust the dry matter of the final product to 30%. In the case of those yams with lower initial dry matter content, no water was added after steaming. The extensibility of the pounded yam doughs was determined by a standard procedure using the Kieffer dough rig under the conditions of tension, probe test speed of 2 mm s⁻¹, distance of 40 mm and trigger force of 0.049 N. The extensibility parameters measured were extensogram peak force, extensibility, and extension area. Results show that dry matter of fresh yam and steamed yam ranged between 22-34% and 21-32%, respectively. All the extensibility parameters were discriminant, especially the extensibility and extension area. Among the most extensible (> 2 mm) accessions were TiViolet and Belep, while the poorly extensible (< 1.3 mm) accessions included Inrax 154, Cirad 235, Rosette, Florido, Defi, and Grand Etang. For the extension area, the accessions TiViolet, Bete Bete, Roujol, Peter, Noulelcae, Regional and Belep had higher extension area (0.15-0.27 N.mm), and the accessions with poor extension area (< 0.08 N.mm) include Malankon, HYB30, Cirad 235, Goana, Pyramide, Defi, and Inrax 154. Significant correlations were found among the dry matter of fresh yam, steamed yam, and the extensogram peak force and extension area. Dry matter may be a good trait for screening yam accessions with good pounded yam extensibility.

Keywords: Extensogram, kieffer dough extensibility, pounded yam, stretchability

Contact Address: Ayetigbo Oluwatoyin, French Agricultural Research Centre for International Development (CIRAD), UMR Qualisud, 34398 Montpellier, France, e-mail: oluwatoyin.ayetigbo@cirad.fr

Orphan crop genomic research trend through integrating text mining and bibliometric analysis

Dejene Bekele Dibaba¹, Meseret Tesema Terfa², Solomon Shiferaw Beyene²

¹*Hawassa University, Plant and Horticultural Science, Ethiopia* ²*Hawassa University, College of Agric., School of Animal and Range Sci., Ethiopia*

Orphan crops are crops with limited attention in global research community. But these crops have many desirable traits in nutrition security, climate change, local adaptation and others. Proper exploitation and use of these important traits are must to tackle current and future climate change and nutritional security issues. The use of genomic tool in the research and development allows to exploit the potential of these neglected crops more effectively and fast. Content and thematic analysis, bibliometric analysis and text mining application are crucial to summaries the status of orphan crops research using genomic tools in the last 23 years. Web of science, Scopus and NCBI data bases was used to retrieve papers using keywords genomic" AND "tool" AND "orphan" AND "crops" for this review. Selection of papers done based on PRISMA guideline and 56 papers selected for the final data extraction. Data analysis and visualisation was done using R software, VOS viewer and Power BI software. The result showed that amount of publication increasing starting from 2017 G.C. 39% of the publication are from India followed by USA and Switzerland. From the papers published, 25 papers are about legumes. Articles & reviews get about 28 and 20 publications respectively. About 41 % which is 23 papers are focused on function whereas 25 % are focused on structure. The result from word cloud showed that the words "crop" and "genome" was mentioned frequently in the reviews. In regard to genomic tool used markers like SNP, EST, SSR and CRISPRCas genome editing are mostly used. Transcriptomics, Genomics, Proteomics, GWAS and RNA seq are the major bioinformatics approach followed by the researchers. Even if the attention given for the orphan crop research showed some advancement recently, a lot of works are remaining in order to understand well and utilise efficiently.

Keywords: Crops, genomics, orphan

Contact Address: Dejene Bekele Dibaba, Hawassa University, Plant and Horticultural Science, Hawassa, Ethiopia, e-mail: dejukominew@gmail.com

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Dairy production and pig production

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Strategies for lowering milk carbon footprints in small-scale dairy farming: A Kenyan perspective

RICARDO GONZALEZ-QUINTERO, PETRONILLE DUSINGIZIMANA, AN NOTENBAERT The Alliance of Bioversity International & CIAT, Tropical Forages, Kenya

Kenya's dairy cattle sector accounts for approximately 15% of the country's total greenhouse gas emissions (GHGE), emphasising the critical need to endorse sustainable dairy production strategies to enhance productivity and ameliorate environmental performance. This study aims to assess milk carbon footprint (CF) reductions through an ex-ante evaluation of mitigation interventions scenarios for 96 dairy farms in Kenya using a cradle to farmgateLife Cycle Assessment approach. Global warming potentials for a 100year time horizon were considered: 27.2 for methane and 273 for nitrous oxide. The functional unit was defined as 1 kg fat and protein-corrected milk (FPCM). The biophysical allocation approach from the IDF Global Carbon Footprint Standard for the Dairy Sector 2022 was used. Data were gathered through a semi-structured survey conducted across 96 small-scale dairy farms in Nandi and Uasin Gishu Counties. Annual on-farm and off-farm emissions were estimated using the 2019 Refinement to the 2006 IPCC guidelines, databases, and local emission factors. In each farm, 6 scenarios were modeled as mitigation strategies: (S1) Improved feeding combined with a 10% increase in milk productivity; (S2) Improved feeding combined with a 20% increase in milk productivity; (S3) Improved feeding combined with a 30% increase in milk productivity; (S4) Removal of males from the herd combined with improved feeding and a 10% increase in milk productivity; (S5) Removal of males from the herd combined with improved feeding and a 20%increase in milk productivity; (S6) Removal of males from the herd combined with improved feeding and a 30% increase in milk productivity. In the improved feeding intervention, natural pasture intake was reduced by 50 %, and replaced with Brachiaria Mulato II for its superior nutritional characteristics. On average, milk CF was 3.0 and 2.6 kg CO₂ eq kg⁻¹ FPCM in Nandi and Uasin Gishu, respectively. CF reductions for each intervention scenario in both counties were as follows: (S1) 14 and 15%; (S2) 20 and 21%; (S3) 25 and 26%; (S4) 21 and 22%; (S5) 26 and 27%; and (S7) 31%. To conclude, milk CF reductions are achievable through measures like enhancing diet quality, increasing milk yields, and culling unproductive male animals from the herd.

Keywords: Cattle systems, climate change, greenhouse gas emissions, life cycle assessment, mitigation potential.

Contact Address: Ricardo Gonzalez-Quintero, The Alliance of Bioversity International & CIAT, Tropical Forages, Nairobi, Kenya, e-mail: r.gonzalez@cgiar.org
Food waste to animal feed: Does it confer milk quality and safety?

Shahin Alam¹, Mullakkalparambil Velayudhan Silpa², Pradeep Kumar Malik³, Raghavendra Bhatta³, Sven König², Eva Schlecht¹

¹University 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*National Institue of Animal Nutrition and Physiology, Bangalore, India*

In view of increasing need to address rising food demand and combat food insecurity, it is alarming that approximately one-third of the global food supply is lost or wasted each year. In India, burgeoning urbanisation, population growth and modernisation of lifestyles in cities are driving a notable increase of food waste (FW) generation. While municipalities must deal with the complexities of FW management, urban and peri-urban dairy farmers face difficulties in sourcing feed for their cows. Consequently, some farmers have resorted to incorporating FW into their cattle rations. However, the effect of feeding these FWs on milk yield, composition, fatty acid (FA) profile and contamination with environmental toxins remains unclear. Therefore, a study was carried out with dairy farmers in the southern Indian megacity of Bengaluru. The study comprised 39 farmers who in total reared 75 cows on diets incorporating on average 23% of FW, and 164 cows fed without FW inclusion. During three visits in winter 2021 (n=74 records), monsoon 2021 (n=61), and summer 2022 (n=104), feed intake, milk yield and quality were determined on a per-cow basis. Milk vield was significantly influenced by season and inclusion of FW into the ration, with cows fed FW and during the winter season having the highest milk yield. Conversely, cows fed FW had lower milk fat yield during the monsoon season, but a 10% higher content of unsaturated FAs compared to milk of cows receiving no FW. Moreover, milk collected during summer contained a higher proportion of unsaturated FAs than milk collected during winter and monsoon (5% difference). No detectable levels of arsenic and cadmium were found in any of the milk samples. Chromium and lead were found in 60% and 28% of the milk samples; with an average concentration 0.011+0.014 and 0.019 ± 0.053 mg kg⁻¹, respectively, which were within WHO's permissible limits. In conclusion, elevated levels of unsaturated FAs in milk from FW-fed cows indicate a promising avenue for providing high-quality food from FW. The negligible heavy metal concentrations in the milk suggest that it remains safe for consumers, even when FW is included in the cows' diet.

Keywords: Alternative feed sources, dairy farming, food waste, India, urban agriculture, waste management

Contact Address: 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

Assessing smallholder farmers' practices on dairy record-keeping in Indonesia

Yuni Resti¹, Maria Wurzinger¹, Lorenz Probst¹, Werner Zollitsch¹, Tera Fit Rayani², Sofiyanti Indriasari³

¹BOKU University, Dept. of Sustainable Agricultural Systems, Austria ²IPB University, College of Vocational Studies, Indonesia ³University of Indonesia, Fac. of Computer Science, Indonesia

Record-keeping is important for dairy farm management to control and monitor livestock productivity. Therefore, this study aimed to investigate the record-keeping practices of Indonesian smallholder dairy farmers and the factors hindering them. The study collected questionnaire data from 82 smallholder dairy farmers in Cisarua, Malang, and Boyolali districts. We also conducted farm observations, focusing on daily farm activities. Statistical and descriptive analyses were performed using SPSS. The study predominantly involved males aged 17 to 65 who generally completed high school education. 74% of the participants had been actively engaged in dairy farming for over a decade, with an average of three lactating cows per farm. The results show that neither educational background nor farming experience influences farmers' decisions to do recording at their farms. The quantity of sold milk was the most recorded parameter. The amount was determined by weight or volume, depending on the equipment used by the milk collectors, and was conducted twice daily in the morning and evening. This study identifies two recording methods implemented for milk sales: manual paper-based and automatic tools, which embed sensors and digital scales linked to a computer system. Reproduction, mainly insemination dates and pregnancy checks, were the second most frequently recorded parameters. Farmers typically write this information on walls, books, or housing barn information boards. Additionally, some cooperatives provide farmers with information cards about animal health and reproductive performance, such as previous health conditions, treatments, and insemination dates. The study also highlighted that no farmers keep individual cow milk production records. Lack of motivation, overwhelming data volume, and a shortage of data interpretation and analysis skills hamper recording activities. However, farmers are keenly aware of the necessity of gathering animal data and the importance of recording data for farm evaluation. An approach that may be considered is to educate farmers on the importance of record-keeping and provide them with information on how to interpret the data effectively. Furthermore, practical strategies such as leveraging digital technologies for data collection may resolve time-related obstacles to data input.

Keywords: Dairy farming, dairy record-keeping, Indonesia, milk production

Contact Address: Yuni Resti, BOKU University, Dept. of Sustainable Agricultural Systems, Gregor-Mendel-Strasse 33, 1180 Wien, Austria, e-mail: yuni.resti@boku.ac.at

Smallholder dairy producers in transition: Dairy market participation and sales in post-Soviet Tajikistan

Alisher Kosimov, Martin Petrick

Justus-Liebig-University Giessen, Institute of Agricultural Policy and Market Research, Germany

The increasing demand for livestock products, as seen in many developing countries, is catalyzing substantial transformations in agri-food value chains and production systems, underscoring the importance of agricultural commercialisation. This transformation is particularly pronounced in post-Soviet Tajikistan, where it intersects with the ongoing transition from a socialist planned and collectivized system to a more market-oriented approach. In this context, smallholder producers, who possess over 93% of the national cattle stock, dominate milk production, which is a crucial daily income source for the majority of the rural population living in prevalent poverty. Despite rapidly growing demand for dairy products and the dairy industry's excessive reliance on imports, not all smallholder dairy producers participate in dairy marketing. Furthermore, among those who do participate in market, there exists a spectrum of participation levels, indicating the necessity for nuanced analysis. Recognizing the crucial role of market integration in stimulating economic growth and reducing poverty, it is essential to investigate the market participation of smallholder producers in Tajikistan. Despite its significance for policy formulation and developmental strategies, particularly amidst Tajikistan's transition towards a market economy, this aspect remains largely unexplored in existing literature. This study examines the key factors driving smallholder producers' decision to participate in dairy marketing and the factors influencing the extent of their participation in terms of sales volume. Data were collected from 302 smallholder dairy producers in Northern Tajikistan using a two-stage random sampling technique, supplemented by qualitative insights from interviews and focus groups. A Heckman two-step regression model was used for analysis. Findings revealed that 67% of smallholder dairy producers participated in dairy marketing. Key factors influencing market participation included access to pasture, investment in pedigree stock and machinery, cropland area, agricultural education, and herd size. The sales volume was affected by marketing contracts, refrigeration facilities, market proximity, and price considerations. The study suggests policy interventions such as improving smallholders' pasture access, providing long-term low-interest credit for intensification investment, facilitating enforceable contracts to strengthen market relations, and improving cold chain and transportation infrastructure to reduce transaction costs.

Keywords: Dairy market participation, Heckman two-step selection model, northern Tajikistan, smallholder producers

Contact Address: Alisher Kosimov, Justus-Liebig-University Giessen, Institute of Agricultural Policy and Market Research, Senckenbergstraße 3, 35390 Gießen, Germany, e-mail: alisher.kosimov@agrar.uni-giessen.de

Can the efforts to intensify smallholder pig production in Uganda be sustained?

Emmanuel Mwema¹, Isaac Rubayiza², Ricardo Gonzalez-Quintero¹, Ben Lukuyu³, Emily Ouma³, Karen Marshall³, An Notenbaert¹

¹*The Alliance of Bioversity International & CIAT, Tropical Forages, Kenya* ²*Ministry of Water and Environment, Government of Uganda, Climate Change, Uganda* ³*International Livestock Research Institute (ILRI), Kenya*

The pig industry supports over two million livelihoods in Uganda. However, surging demand for pork and related products strains resources and affects the environment. This study evaluates the productivity and environmental impacts of smallholder pig intensification in the Masaka and Mukono districts of the central region of Uganda. These areas have pronounced rural-rural, rural-urban, and urban-urban value chain domains and thriving pig production driven by urbanisation and favourable market conditions. We conducted a literature search of six publications and identified extensive and intensive production systems as the prevalent systems across study sites. We then extracted data on herd size and composition, diets, and productivity. These were further validated by stakeholders, including the district's livestock experts. This followed a mapping exercise to prioritise interventions into two: (i) focused; includes pig biosecurity, genetics, and manure management (ii) integrated; incorporates optimised, improved feeding into the focused intervention. Both interventions were proposed for extensive systems, while integrated interventions were suggested for intensive systems. CLEANED tool (https://alliancebioversityciat.org/ tools-innovations/cleaned) was applied to estimate these interventions' potential environmental and productivity trade-offs. Environmental domains assessed include land requirement (ha/yr; ha/MT pork), soil health (N balance; t soil/year; kg; soil/ kg pork), water use $(m^3/year; m^3/kg pork)$, and greenhouse gas (GHG) emissions (t CO_2 eq./year; kg CO_2 eq. /kg pork). Results showed that integrated and focused interventions minimise environmental effects per unit product. Integrated interventions achieved environmental efficiency gains of 54.07% to 54.59% and 55.65% to 65.43%across production systems in Mukono and Masaka, respectively. The integration, however, raised the total absolute environmental footprints ranging from 49.53 % to 110.03 % and 62.27 % to 79.49 %, respectively. A focused package performed better in Masaka (52.45%) than Mukono (37.53%) but increased absolute total footprints by 185.72% and 146.86%, respectively. Generally, extensive systems were more suited for integrated than focused interventions. Intensifying extensive systems decreased GHG emission intensity between 1.92 and 3.94 kg CO_2 eq. for every kilo of pork produced. Proper manure management and improving the reproductive performance of pigs through breeding, biosecurity measures, and optimised diet intake can balance both production and environmental goals, eventually sustaining the pig industry.

Keywords: CLEANED, environmental impacts, smallholder systems

Contact Address: Emmanuel Mwema, The Alliance of Bioversity International & CIAT, Tropical Forages, 00621 Nairobi, Kenya, e-mail: e.mwema@cgiar.org

Digital innovations to develop monitoring indicators for infertility issues in dairy animals

Kiruthika Nallasamy, Shanthra Prakash, Arunkumar Krishnamoorthy, Thanammal Ravichandran

Kumaraguru Institute of Agriculture, Dept. of Animal Husbandry, India

India is the highest milk producer in the world, with an annual production of 230 million tons and a bovine population of 300 million. Despite being number one in milk production, dairy productivity in India is exceptionally low (1172 liters per lactation). The major factors that influence low dairy productivity are poor reproductive performance, a lack of quality feed and fodder and poor animal healthcare facilities. Suboptimal and poor reproductive performance, such as less production, anoestrus, long dry period, and less lactations and escalation in management cost results in poor reproductive efficiency in dairy cattle and consequently, 20-30 million tons of milk are lost annually, which amounts to a loss of INR 50000 crores. Many digital tools are dawning in India for collecting data on reproductive performance in dairy animals. This study was aimed at understanding the use of digital tools in monitoring the reproductive performance of dairy animals in southern India. The data were collected from 2123 cows and 135 buffaloes from 30 villages in Tamil Nadu state. Herd structure analysis indicated that 90 % of cows were Jersey and Holstein Friesian crossbreds and 46 % of cows and 30 % of buffaloes were milking. A higher proportion of animals were found in second to fourth lactation (59%). A greater percentage of calves were observed in the buffalo population (60%) than in cows (46%). It was observed that 15% of heifers were not inseminated up to 30 months of age, and 32 % of calves were not inseminated even after 6 months of calving due to problems such as anestrous, poor heat detection, and poor growth. Among the inseminated animals, 18 % of the 404 animals were found to be repeat breeders, which are inseminated more than three times. This data analytics was used for evidence-based extension activities to enhance the reproductive efficiency of dairy animals. It has been found that digital tools help healthcare providers and extension agents counsel farmers effectively.

Keywords: Dairy, digital application, digital innovation, infertility, repeat breeding

Contact Address: Thanammal Ravichandran, Kumaraguru Institute of Agriculture, Dept. of Animal Husbandry, 1P1, Tower 5, KGISL Platina, Keeranatham, 641035 Coimbatore, India, e-mail: thanamvet@gmail.com

Implications of increased dairy production in poor market access areas: An *ex-ante* analysis in Senegal

Derek Chan¹, Sirak Bahta²

¹International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Senegal

²International Livestock Research Institute (ILRI), Policy, Institutions and Livelihood, Kenya

Access to market is vital for farmer livelihoods, especially for time-sensitive products such as dairy. Interventions that target increased dairy productivity may not translate directly to increased farmer income if market access is poor, even in countries that are net importers of dairy products, such as in Senegal. In this study, we conduct a comparative ex-ante scenario analysis on the impacts of increased dairy production in two areas, one that has easy market access and another that has poor market access. We surveyed 119 milk-producing agro-pastoral households in two different clusters, one in the region of Thies that has ready road access and is within one hour on motorized transport to the city of Thies and within two hours to the large urban market of Dakar, and a second in the region of Louga within the sylvopastoral zone that averages 40 km from the closest paved road and far from major urban centres. Milk production in both areas is primarily from indigenous breeds, which produce between 1–31d⁻¹, with 117% and 185% higher milk productivity for Thies and Louga respectively during the rainy season as compared to dry season, which lasts nine months out of the year. By comparing the milk production, transformation and sales practices of these farming households, we find differing strategies to respond to the seasonal variation, which has implications on household nutrition and incomes. We capture this decision-making structure quantitatively, and conduct analysis by using a dynamic simulation model, considering the entire value chain including access to pasture, costs of additional feed, sales prices, the seasonality, possibilities of processing as well as access to market. Through testing scenarios of production changes and its impact on the value chain, we find that without adequate access to market, households increase gifts to relatives and transform greater quantities to butter oil, a preservable form, but requires significant work and has lower income per litre milk produced and lower demand. This study has important implications on development of the dairy value chain, especially in areas that have poor market access.

Keywords: Access to market, dairy, Senegal, value chain

Contact Address: Derek Chan, International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Mamelles, 12300 Dakar, Senegal, e-mail: d.chan@cgiar.org

Season effects on milk production and composition from White Fulani and Gudali zebu cows under grazing system in Benin

BOSSIMA IVAN KOURA, YOROU N'GOBI DOUAROU, BOYA ANDRÉ ABOH Université Nationale d'Agriculture (UNA), Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, Benin

In sub-Saharan Africa, climate change affects pasture availability and forage nutritional value, negatively impacting milk production. White Fulani and Gudali cows are two breeds introduced in Benin to improve milk production. However, little information exists about the performance of these breeds, particularly during the dry season when forage is of poor quality. This study aims to compare feed intake and milk production by the two breeds grazing in the same grassland during the dry season to identify the breed more likely to sustain milk production in a changing climate. The study was conducted in the semi-arid area of Benin (Kétou region) during the early (S1) and late (S2) dry seasons. The hand-plucking method was used to estimate cows' feed intakes. 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 intake was higher $(14.92 \text{ kg day}^{-1})$ in White Fulani than in Gudali $(13.23 \text{ kg day}^{-1})$. 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 $(1.72 \text{ L day}^{-1})$ than White Fulani $(1.2 \text{ 2L day}^{-1})$. Milk from Gudali has more fat (5.57%) than White Fulani (5.10%). However, White Fulani had higher milk protein content (3.29%) than Gudali (3.11%). The study showed that the Gudali cows ingested less forage but had higher milk production. Further studies could investigate the effect of accurate supplementation in improving milk production and composition in the two breeds.

Keywords: Climate change, fat, milk offtakes, protein, sub-Saharan Africa

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

Extending the shelf-life of raw milk in sub-Saharan Africa using a passive cold chain solution

OGHAIKI ASAAH NDAMBI¹, LOTTE STAELENS², ZELALEM YILMA³ ¹Wageningen University & Research, Animal Science Group, The Netherlands ²IKIC Impact Ventures, Belgium ³Netherlands Development Organisation, Ethiopia

In most sub-Saharan countries, milk marketing systems suffer from poor milk quality, unfunctional quality control systems, and no pricing based on quality or demand/supply fluctuations. Much of the marketed milk passes through unorganised (informal) transactions such as farmer-to-consumer direct transactions on a contractual basis, at producer or trader-owned small milk shops, and open local markets. In Ethiopia, the volume of milk channelled through the formal milk market accounts for less than 20% of the total volume of milk marketed at the national level. Except in a few cases, only morning milk, collected by dairy cooperatives, individual traders, and milk processors, reaches the few processing plants operating in and around Addis Ababa. Moreover, only a small proportion (under 10%) of the milk producers in high dairy potential areas have access to the formal milk market channel most of whom do not sell evening milk because they are not able to cool their milk, safely store and transport it the following day.

IKIC Impact Ventures BV, a Belgium-based company, is piloting a passive cold chain solution that preserves evening milk till morning. The solution uses thermostatic batteries (Orbs) with stainless steel casings containing a phase-changing material, which allows a stable and predictable cooling environment for temperature-sensitive products such as milk.

This study monitored the temperature and pH of milk stored in three treatments: i) filled milk cans with Orbs and fitted in an insulating case, ii) milk cans with Orbs stored without an insulating case and iii) cans filled with milk, without Orbs and without an insulating case. The results show that this recent technology effectively lowered temperature and slowed down acid formation in milk. Using an insulating case improved the effectiveness of the technology which maintained milk quality overnight in Ethiopia, making evening milk suitable for processing the next day.

Keywords: Ethiopia, food safety, IKIC impact ventures, milk cooling, milk quality, preservation

Contact Address: Oghaiki Asaah Ndambi, Wageningen University & Research, Animal Science Group, Wageningen, The Netherlands, e-mail: asaah.ndambi@wur.nl

What drives dairy farm food safety practices in Bangladesh? Evidence from a PLS-SEM model

Fardous Ara Happy, Sebastian Hess

University of Hohenheim, Dept. of Agricultural Policy and Market Analysis, Germany

Milk production in Bangladesh has been growing in recent years along with the expansion of commercial dairy markets. However, the structure of dairy farming in Bangladesh is still overall resource-poor and small-scale, and constitutes a primary- or subsistence occupation to many farmers with markets shaped by informal nearby selling points. Commercial milk collection centres and the availability of farm door-level local milk collectors at rural dairy villages had encouraged more dairy producers to be market oriented. However, poor food safety practices result in rapid disease transmission among cows and contaminated marketable milk. Therefore, improved farm hygiene practices would be of great benefit for milk quality and safety in Bangladesh. In this study, a total of 498 non-subsistence dairy producers from three different agroclimatic zones in Bangladesh were personally interviewed. Six major groups of food safety practices were formed from 73 food safety measures that were surveyed at the farm level. The resulting categories represent safety issues during milking, milk storage, health management, hygiene record keeping and cow raising environment. Partial least square structural equation modelling (PLS-SEM) was adopted to analyse measurement models of the latent variables named knowledge, attitude, barriers, farm resources and food safety with their respective multiple indicators (>= three indicators for each construct reflection). The inner model was developed with possible interaction among the latent variables whereas the food safety index was the main latent endogenous variable in the model. The estimated direct path coefficient towards the food safety index indicated that higher hygiene knowledge and attitude significantly induced producers to intensively adopt safety measures. However, farm resources enhanced adoption of safety practices indirectly, through its direct significant effect on knowledge and attitude. Surprisingly, safety inspection institutions had no significant effect on milk safety oriented dairy farm management. From the multigroup analysis, rather no constructs were found to exhibit significant differences between different dairy markets and climate zones. Therefore, it cannot be rejected that milk hygiene issues in Bangladesh are primarily subject to individual- and household level decisions, while structural and geographical issues seem to be of minor importance.

Keywords: Bangladesh, dairy farm, food safety, PLS-SEM

Contact Address: Fardous Ara Happy, University of Hohenheim, Dept. of Agricultural Policy and Market Analysis, Schloß Hohenheim 1, 70599 Stuttgart, Germany, e-mail: fardousara.happy@uni-hohenheim.de

Opportunities and challenges of collecting and utilising monitoring data from livestock value chain actors

Nils Teufel¹, James Rao¹, Yanamani Nepali², Braja Swain³, Varijaksha Padmakumar², Joseph Auma¹, Guanghong Xu⁴, Godfrey Ngoteya⁵, Josué Awonon⁶, Amos Omore⁵

¹International Livestock Research Institute (ILRI), Kenya ²International Livestock Research Institute (ILRI), Nepal ³International Livestock Research Institute (ILRI), India ⁴UC Santa Cruz, Development Economics, United States ⁵International Livestock Research Institute (ILRI), Tanzania ⁶Tufts University, Economics, United States

Improving the efficiency of value chains and the collaboration between various value chain actors are major objectives of many rural development interventions aiming to achieve market-based, sustainable changes in livelihoods. However, the available data for assessing value chain activities and interactions is often very limited. Group-based approaches can yield good insights into the basic structure of value chains and the roles of major actor groups, as well as of averages prices for various product groups along the chain. However, the heterogeneity of actors as well as the considerable variation of many indicator variables over time cannot easily be captured by such an approach. For this, continuous data collection by the value chain actors themselves is required. However, establishing robust and efficient systems for generating such data which also provide useful information for the relevant actors themselves is challenging. Within the CGIAR initiative on Sustainable Animal Productivity (SAPLING) several such systems have been developed for intensifying dairy value chains in 3 countries: Kenya, Tanzania and Nepal. They are linked to last mile providers of information, inputs and services, generically known as livestock agents, who have been supported by the initiative in the strengthening and growth of their businesses through business incubation and technical training. Monitoring systems have been developed based on their sales activities, their interactions with other actors and on the recording of livestock management and performance data. Initial results after several months of implementation show that the number of data records is greatest where a wellestablished data platform is an integral part of the incubation and training system as well as of sales transactions and extension activities. However, actors can contribute more to developing a system suited to their own needs if simpler stand-alone approach is selected. Monitoring data generated through the recording of livestock performance and management provides only limited insights into the progress of livestock agents towards developing their businesses. However, all three approaches presented here are maintained by outside research and development institutions.

Keywords: Data collection, livestock development, monitoring, value chains

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

Business planning for commercialisation of livestock vaccination services: The case of Rift Valley Fever vaccine in Kenya

Francis Wanyoike, Bernard Bett, Sirak Bahta

International Livestock Research Institute (ILRI), Kenya

This study was meant to inform successful rollout of commercialised Rift Valley Fever (RVF) vaccination services in Kenya for greater effectiveness in disease outbreak mitigation. The analysis focused on 3 contrasting counties in terms of livestock production systems including Muranga, Laikipia and Isiolo. The approach used was adapted from the USAID's Center for Accelerating Innovation and Impact (CII) guide on business planning during introduction of new innovations in human health in new countries. The methodology consists of 3 steps including identification of geographical regions where potential for success is highest; conducting an in-depth assessment of the market including determination of opportunities and barriers to scale-up of the innovation; and developing a strategy for overcoming barriers.

Constraints and opportunities to successful commercialisation of the vaccine varied across counties. Owing to public the benefits that accrue from vaccinating, the commercialisation of the vaccine could take the form of occasional campaigns involving Public Private Partnerships (PPPs). An important barrier to successful commercialisation is the widespread lack of knowledge about RVF among farmers which undermines demand for the vaccine. Vaccination campaigns should therefore feature education of livestock producers about the disease. The possibility of success of commercialisation was found to be highest in Murangá. In Laikipia and Isiolo, chances for success were rated as modest and lowest, respectively. A major constraint in the latter two counties is the culture of dependency on free vaccines provided by donors often responding to emergencies including disease outbreaks and droughts. Vaccination campaigns should henceforth be scheduled as disease outbreak mitigation strategies instead of emergency responses and cost recovery from prices that farmers are charged should be balanced against potential vaccination coverage.

Keywords: Commercialisation, vaccination, Rift Valley Fever

Contact Address: Francis Wanyoike, International Livestock Research Institute (ILRI), Policy Institutions and Livelihood (PIL), Naivasha Road, 00100 Nairobi, Kenya, e-mail: f.wanyoike@cgiar.org

Farm-level impacts of business development support to last-mile providers of dairy inputs and services in Tanzania

JAMES RAO¹, NILS TEUFEL¹, JOSUÉ AWONON², GODFREY NGOTEYA³, AMOS OMORE³ ¹International Livestock Research Institute (ILRI), Kenya ²Tufts University, Economics, United States ³International Livestock Research Institute (ILRI), Tanzania

The productivity of livestock in intensifying small-holder dairy systems is often constrained by limited access to inputs and services as well as low levels of technical knowledge due to the inadequacy in public extension systems. So far, private sector providers of inputs and services have not been able to penetrate small-holder markets as costs for delivering specific products to dispersed and small-scale producers are high. On the other hand, livestock technologies deliver greatest benefits when adopted in combination. For instance, the potential of genetic improvements through artificial insemination can only be achieved with appropriate feed management and nutrients can only be utilised if parasites are controlled. However, private sector providers are often restricted to specific inputs and services and have also limited technical understanding of all aspects of dairy production to provide appropriate advice to small-scale producers. Therefore, the CGIAR initiative on Sustainable Animal Productivity (SAPLING) has introduced interventions to support last-mile providers in developing more holistic businesses and strengthening their technical capacity in several countries. In Tanzania 100 existing local agripreneurs were recruited into a programme introducing them to a digital communication and sales platform, which eases transactions with their dairy farmer customers and up-stream suppliers. Half of these agripreneurs, randomly selected, were then included in a 15-week business incubation and technical training programme, beginning in December 2023. A survey of farmers, sampled from those linked to all agripreneurs at the beginning of the incubation programme, allows the causal determination of the intervention's impacts on farmers' purchases of inputs and services, their livestock management, and their success in dairy farming. The results highlight the benefits of bundling inputs and services for the development of the agripreneurs' businesses and for the productivity of the farmers' livestock.

Keywords: Business development, dairy development, extension, impact assessment, last-mile delivery, Tanzania

Contact Address: James Rao, International Livestock Research Institute (ILRI), 30709-00100, Nairobi, Kenya, e-mail: j.rao@cgiar.org

Diagnosis of porcine cysticercosis using rat basophilic leukemia (RBL) IgE reporters and loop-mediated isothermal amplification (LAMP) technology

Md. Shahadat Hossain¹, Zhiru Li², Phil Toye², Lian Thomas³, Franco H. Falcone¹

¹Justus Liebig University Giessen, Institute of Parasitology, Germany ²New England Biolabs, United States

³*International Livestock Research Institute (ILRI), Kenya*

Cysticercosis is a neglected zoonotic disease caused by larval stages of *Taenia solium*, with a huge impact on public health (neurocysticercosis in the brain) and the livelihoods of small-scale pig farmers in many low-income countries. Diagnosis of porcine cysticercosis is mostly based on tongue palpation and carcass inspection, complemented by IgG-based serological analyses. These diagnostic methods often show crossreactivity or are not sensitive enough in pigs with low infestation. Here, we describe the development of a pig Immunoglobulin E (IgE) reporter system and selection, cloning, and recombinant expression of candidate diagnostic allergens of T. solium. In addition, we adopted a molecular approach using loop-mediated isothermal amplification (LAMP) technology to distinguish cysticercosis caused by T. solium from the related, co-endemic *T. hydatigena* (non-zoonotic). For developing the reporter system, Rat Basophilic Leukemia Neuropeptide Y-monomeric Red Fluorescent Protein expressing cells (RBL NPY-mRFP) were transiently transfected with a pig/rat highaffinity IgE receptor alpha chain (Fc ϵ RI α) chimeric construct followed by antibiotic selection for stable transfectants. Putative IgE-binding T. solium allergens were selected by a combination of published work on transcriptomic and proteomic data and allergenicity predictions. Chosen allergens were cloned into expression vectors and transiently transfected into HEK-2936E cells in suspension. In LAMP method, we targeted cytochrome c oxidase 1 (cox1) gene of T. solium and T. hydatigena, incubated LAMP reactions at 65°C for 30 min and recorded the post-amplification colour (yellow-positive, pink-negative). Stable transfection of the chimeric pig-rat Fc ϵ RI α was confirmed at the mRNA level by RT-PCR. Five candidate *T. solium* oncospheral diagnostic allergens (E5LBB8, K0A0S9, Q2XNL7, Q9NI46, W8P1J2) were identified through bioinformatic analysis and three HEK293-6E transfected allergens showed expected protein band size in Western blot analysis upon recombinant expression. The LAMP assay was able to detect 10 pg μ L⁻¹ of T. solium DNA in pig serum, without cross-reactivity with *T. hydatigena*. We are now focusing on the detection of *T. solium* DNA through LAMP assay in field studies. This study shows proof-of-principle for a serological reporter assay for a lab-based approach, while LAMP is expected to introduce a field-applicable point-of-care test for porcine cysticercosis.

Keywords: Allergen, cysticercosis, diagnosis, reporter system, *Taenia hydatigena*, *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

Melbe camel a unique genetic resource and their contribution towards food security of Boran region, Ethiopia

Ahmed Nura¹, Sandip Banerjee², Mestawet Taye³

¹Borana University, Animal Science, Ethiopia ²Adamas University, School of Smart Agriculture, India ³Hawassa University, School of Animal and Range Sciences, Ethiopia

Borana region (between. 4°3'N to 5°0'N and 37°4'E to 38°2'E) of Ethiopia is bestowed with rangelands and is the home of the famous Boran cattle. Lack of sufficient rainfall followed by long periods of drought, over grazing has led to the degradation of the rangeland and are being replaced by thorny bushes and tree species (Acacia) which are well adapted to the hot arid region. The large herds of Boran cattle are being slowly replaced by goats and camels. This is because the camels and goats are better adapted to the agro ecology especially and they can browse on thorny bushes and acacia species. Melbe camel is a hetro unreported breed of dwarf camel which is reared in Dillo and Dirre districts of Borana zone, Ethiopia. The camel are native of Melbe desert by the members of "Gabra" tribe. Melbe camel is a dwarf breed of camel when compared to the commonly available breed of camel locally known as loge. The Melbe camel has a white coat, quite aggressive and can thrive well on scarce halophyte vegetation's and can survive on highly brackish water which are avoided by the Joge camel and other livestock species. The Melbe camel can survive on less and brackish water and require water once in for several days when compared to Joge camel's. Melbe camels are tolerant towards the locally prevailing diseases and are raised for their milk and are also a source of saving for their owners. They are an important genetic resource and need to be conserved immediately

Keywords: Borana, Ethiopia, food security, Melbe camel

Contact Address: Sandip Banerjee, Adamas University, School of Smart Agriculture, Adamas knowledge city barasat - barrackpore road jagannathpur, 700126 Barberia, India, e-mail: sansoma2003@yahoo.co.in

Agronomic characteristics of five native forage species and their preference by Djallonké sheep in Benin

CLICILLA HESSA MONTCHO, BOSSIMA IVAN KOURA, BOYA ANDRÉ ABOH Université Nationale d'Agriculture, Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, Benin

In sub-Saharan Africa, cultivation of drought-resilient plant species can offer a promising solution to address forage shortage and quality due to climate change. This study aims to evaluate the agronomic characteristics of five native drought-resilient grasses, namely Andropogon virginicus, Cenchrus biflorus, Brachiaria deflexa, Dactyloctenium aegyptium, and Panicum maximum. Then, to evaluate the foraging preference of these species by sheep. The species were cultivated at the Agricultural Entrepreneurship Promotion Center in Kétou from July to November 2023 in 20 plots of $3 \text{ m} \times 3 \text{ m}$. The experimental design was a randomised complete block design with five (05) forage species as treatment and four (04) replications per treatment. The cultivated plants were compared based on their morphological traits: leaf appearance rate (LAR), phyllochron, leaf elongation rate (LER), number of leaves per tiller (NLT), and final leaf blade length (FLL), as well as their biomass production and nutritional value at 45 days (at stem elongation stage) and 90 days (at maturity stage). The voluntary intake and intake rate of each forage species by Djallonké sheep were assessed. D. aegyptium (LA: 24.44 cm; NLT: 6.73 cm) and *B. deflexa* (LA: 25.56 cm; NLT: 5.60 cm) showed the highest value (p < 0.05) of leaf appearance and number of leaves per tiller. B. deflexa had the highest (p < 0.05) number of leaves at different evaluation stages (145.53 leaves at 30 days; 305.28 leaves at 60 days) than the other species. Regarding biomass production at 45 days, *P. maximum* ([976.50] kg ha⁻¹) ranked first, and *A. vir*ginicus produced less ([58.50] kg ha⁻¹). Sheep preferred more *D. aegyptium* (intake: 48.92 g MS) and less C. biflorus (intake total: 31.13 gMS). The results showed that D. aegyptium and B. deflexa could be suitable for growing ruminants in a changing climate.

Keywords: Andropogon virginicus, Brachiaria deflexa, Cenchrus biflorus, climate change adaptation, *Dactyloctenium aegyptium*, sub-Saharan Africa

Contact Address: Clicilla Hessa Montcho, Université Nationale d'Agriculture, Ecole de Gestion et d'Exploitation des Systèmes d'Elevage, BP 43, Kétou, Benin, e-mail: edjonamontcho@gmail.com

Enhancing dairy production and farm income through irrigated fodder adoption: Evidence from smallholder producers in Ethiopia

Sisay Getaneh^{1,3}, Delelegne Abera², Melkamu Bezabih³, Ermias Tesfaye Teferi⁴

¹Amhara Agricultural Research Institute, Ethiopia

²Hawassa University, Agricultural Economics, Ethiopia

³International Livestock Research Institute (ILRI), Ethiopia

⁴The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Ethiopia

This study examines the economic impacts of adopting irrigated fodder among small-scale dairy farmers in Ethiopia. The study utilises cross-sectional data from 351 dairy producers in four districts from the southern, central and northern parts of the country, consisting of 181 adopters and 170 non-adopters, collected in 2021. The research employs propensity score matching (PSM) and endogenous switching regression (ESR) techniques to evaluate the impact of adopting irrigated fodder on milk yield, dairy income, and total farm income. The Rosenbaum limits approach is used to achieve covariate balancing and address the impact of unobserved selection bias. Results show that education, irrigated land size, milking cow ownership, extension service, dairy cooperative membership, dairying experience, and farmer breed types positively affect irrigated fodder technology adoption. The Propensity Score Matching (PSM) results show that farmers who grow fodder have much higher milk productivity (2.54 liters per cow), dairy revenue (2,228.42 ETB y^{-1}), and overall farm income (8,566.96 ETB y^{-1}) than farmers who do not, demonstrating enhancements in milk production (2.87 litres per cow), dairy earnings (3,975.08 ETB), and total farm income (10,427.20 ETB) among those who have adopted it. The findings indicate that the use of irrigated fodder technology has a substantial positive impact on milk productivity, dairy revenue, and overall farm profitability. The research highlights the significance of ongoing efforts to enhance skills in irrigated fodder management and provide advice to promote the adoption of irrigated fodder among those who have not yet adopted it and to maintain the advantages for those who have already adopted it.

Keywords: Dairy revenue, ESR, Ethiopia, irrigated fodder, milk production, PSM

Contact Address: Sisay Getaneh, Amhara Agricultural Research Institute, Bahir Dar, Ethiopia, e-mail: gesisay21@gmail.com

Comparative analysis of market-oriented and subsistence pig farmers' traits preferences and selection criteria in Burkina Faso, West Africa

Dominique Ouédraogo¹, Salifou Ouédraogo-Koné², Badjibassa Akounda³, Bendi Tandamba², Albert Soudré³, Gábor Mészáros⁴, Maria Wurzinger⁴, Johann Sölkner⁴

¹Joseph KI-ZERBO University, University Center of Ziniaré, Burkina Faso

²Nazi Boni University, Inst. of Rural Development, Burkina Faso

³Norbert Zongo University, Training and Research Unit in Sciences and Technologies, Burkina Faso

⁴BOKU University, Dept. of Sustainable Agricultural Systems, Austria

In Burkina Faso, pig production is constantly increasing due to the growing demand for pork meat. This trend can be explained by demographic data, urbanisation and the emergence of a middle class. Pigs are reared in two main production systems, namely subsistence and market-oriented farming. This study has been carried out to understand pig farmers' traits' preferences and their selection criteria. A total of 386 farmers from rural and peri-urban areas were interviewed using focus group discussions methods and semi-structured questionnaires. Data were analysed using R. Descriptive statistics were done, means and standard deviation of quantitative variables were computed and compared using Tukey Test. At the same time frequencies were calculated for qualitative variables and Pearson's Chi-squared test and Fisher's exact test used for comparison. Reasons for keeping pigs, breed preferences and selection criteria were assessed by computing indexes or ranking. The results show that pig farmers were predominantly men and public employees in the market-oriented system (MS) while women having crop farming as main activity dominate in the subsistence system (SS). The two systems were significantly (p < 0.05) different regarding the sex of farmers and their main activity. In both systems, earning income was the main reason for keeping pigs (Index = 0.484 in CS and 0.496 in SS) followed by manure, wealth and household consumption in various order. For breed preferences, market-oriented farmers prioritised prolificity (Index = 0.404) and fattening weight (Index = 0.374) while subsistence farmers preferred fattening weight (Index = 0.371) first, followed by prolificity (Index = 0.290). Breed and body size were the most preferred traits for the selection of breeding sow and boar in the two systems, but their relative importance varied according to the system. For breeding sow, indexes of breed and body size were 0.389 and 0.350 in MS and 0.394 and 0.367 in SS. These values for breeding boar were 0.408 and 0.351 in MS and 0.391 and 0.374 in SS. Regarding that the productive features of animals were mostly preferred by farmers in both production systems, improvement strategies should target these traits to improve their livelihoods.

Keywords: Burkina Faso, market, pigs, subsistence, trait preferences

Contact Address: Dominique Ouédraogo, Joseph KI-ZERBO University, University Center of Ziniaré, 7021 Ouagadougou, Burkina Faso, e-mail: ouedom@gmail.com

Advancing cattle genetics: A comparative exploration of innovation systems in Kenya and Uganda

Benadette Ayebare

University of Hohenheim, Dept. of Social and Institutional Change in Agricultural Development (490c), Germany

Enhancing livestock production, disease resistance, and environmental resilience in developing countries is pivotal to meeting the increasing demand for animal-based foods amid urbanisation, rising incomes, and climate change impacts. Livestock development in developing countries is characterised by a complex interplay of challenges including limited access to resources, inadequate infrastructure, and the need for sustainable practices to meet growing demands for food security and economic growth. Improving livestock breeds is a key strategy to bolster productivity and resilience. This study employed the Functional-structural analysis within the Agricultural Innovation Systems framework to conduct a comparative examination of the evolution, current status, key actors, challenges, opportunities, and critical complementary activities within the cattle genetic innovation systems of Kenya and Uganda. The current state of cattle genetics in Uganda and Kenya is marked by ongoing efforts to improve breeding initiatives, despite variations in progress and infrastructure between the two countries. Data collection methods included document reviews, expert interviews, focus group discussions, and net-maps. Findings indicate the initiation of genetic improvement initiatives in the early 20th century in Kenya and the mid-20th century in Uganda and show that, to date, there is substantial public sector involvement in the cattle genetics sector. Common challenges across both countries include limited farmer knowledge, inadequately regulated genetics policies, stakeholder collaboration constraints, and technical capacity limitations. The other major challenges faced in Kenya are a focus on high-potential areas (highland areas) and the dairy sector. Similarly, Uganda grapples with expensive resource limitations and weak national breeding programs. Identified critical complementary activities encompass nutrition and pasture management, animal housing and general care, and veterinary care services. The study recommends increasing investment and funding for the cattle genetics sector and services, streamlining policy reform and implementation, fostering stakeholder collaboration, strengthening farmer education, promoting cultural sensitivity and awareness, and increasing investment and engagement in complementary activities. These insights help identify crucial areas for genetic improvement within cattle genetic innovation systems in Kenya and Uganda, with potential applicability to countries sharing similar socio-economic factors.

Keywords: Agricultural innovation systems, cattle genetics, comparative study, functional-structural analysis, Kenya, Uganda

Contact Address: Benadette Ayebare, University of Hohenheim, Dept. of Social and Institutional Change in Agricultural Development (490c), Paracelsussstrasse, 70599 Stuttgart, Germany, e-mail: benadette.ayebare@uni-hohenheim.de

Prevalence and risk factors of anoestrus and repeat breeding in dairy cows

Md. Ashikur Rahman Bhuiyan, Muhammad Riazul Islam, Farida Yeasmin Bari, Mohammad Musharraf Uddin Bhuiyan

Bangladesh Agricultural University, Dept. of Surgery and Obstetrics, Bangladesh

The purpose of this study was to determine the prevalence of anoestrus and repeat breeding and its influencing risk factors at selected areas of Cumilla district in Bangladesh. The data were collected on cows breed, age, BCS, parity, peak milk vield, occurrence of anoestrus and repeat breeding from 321 cows of two Upazilas of Cumilla district using questionnaire. The prevalence of anoestrus was 9.3% (30/321) and the prevalence of repeat breeding was 7.5% (24/321). The highest prevalence of anoestrus (41.7%) was observed in local cows and the lowest was observed in Friesian cross counterpart (5.0%). The highest prevalence of repeat breeding (22.7%) was observed in Sahiwal cross and the lowest was observed in Jersey cross counterpart (3.7%). The highest prevalence of anoestrus (35.7%) was observed in 73–96 months old cows and the lowest was observed in 24–48 months old counterparts (11.0%). The highest prevalence of repeat breeding (28.6%) was observed in 73-96 months old cows and the lowest was observed in 24-48 months old counterpart (8.7%). The prevelance of anoestrus was the highest 26.7% in cows with BCS of 3.5 and was the lowest 4.9% in cows with BCS of 3.0. The highest prevalence of repeat breeding (26.7%) was observed in cows with 3.5 BCS and the lowest was observed in 2.5 BCS counterpart (4.4%). The highest prevalence of anoestrus (14.3%) was observed in cows with 4–7 parity and the lowest was observed in 2–3 parity counterpart (6.3%). The highest prevalence of repeat breeding (12.2%) was observed in cows with 1 parity and the lowest was observed in 2–3 parity counterpart (4.5%). The highest prevalence of anoestrus (40.2%) was observed in cows vielded 1–51d⁻¹ milk and the lowest was observed in cows yielded 11–201d⁻¹ counterpart (7.5%). The highest prevalence of repeat breeding (20.0%) was observed in cows yielded $1-51d^{-1}$ milk and the lowest prevalence was observed in cows yielded 11–201 d⁻¹ counterpart (5.4%). The difference in prevalence of anoestrus and repeat breeding among breeds, BCS and age groups was significant (p < 0.05). In conclusion, the prevalence of anoestrus and repeat breeding was 9.3% and 7.5%, respectively which might be influenced by breed, age and BCS of cows.

Keywords: Anoestrus, dairy cows, prevalence, repeat breeding, risk factors

Contact Address: Muhammad Riazul Islam, Bangladesh Agricultural University, Dept. of Surgery and Obstetrics, Bau Campus, 2202 Mymensingh, Bangladesh, e-mail: mrislam82@gmail.com

Strategies for sustainable livestock systems

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Evaluating the potential environmental co-benefits of perennial grass-legume mixtures in Ethiopia

An Notenbaert¹, Emmanuel Mwema¹, Regassa Bekele², Eyuel Girmay², Solomon Mwendia¹, Kalkidan Ayele Mulatu²

¹*The Alliance of Bioversity International & CIAT, Kenya*

²The Alliance of Bioversity International & CIAT, Tropical Forages, Ethiopia

While livestock plays a crucial role in the livelihoods of Ethiopian farmers and the overall economy, it also contributes to land degradation. The scarcity of land compels livestock to rely heavily on overgrazed natural pastures for feed intake. This contributes to Ethiopia's high rates of soil erosion and land degradation, thus posing a significant threat to ecosystems and livelihoods. With climate change projected to exacerbate this issue, there is an urgent call for action towards the implementation of innovative farming systems that simultaneously increase yields, safeguard natural resources, and foster economic growth. Consequently, the EthiopiaGrass project aims to develop integrated grassland-cropping systems that address this challenge through testing of multipurpose forages and grass-legume mixes for enhancing livestock feed provision, increasing food crop production, and simultaneously improving soil quality. During on-station trials in North and Southern Ethiopia, several grasslegume mixtures were identified as more productive than monocultures and having positive effects on soil quality, carbon storage, and nutrient cycling. Participatory farmer-led testing amongst more than 300 farmers confirmed their acceptability by smallholders and revealed specific trait preferences and adoption patterns. This paper presents a quantitative assessment of the environmental benefits of widespread adoption of such grass-legume mixes in Ethiopia's mixed crop-livestock and specialised dairy systems. We parametrized the CLEANED model (www.alliancebioversityciat. org/tools-innovations/cleaned) with secondary data on livestock numbers, herd composition, and productivity, along with empirical data from trials, adoption rates from participatory assessments and feed basket compositions from G-FEAST assessments (www.ilri.org/news/gendered-feed-assessment-tool-g-feast). The results demonstrate significant environmental benefits of forage grass-legume mixes, including a nearly 20% reduction in land requirement per liter of milk, up to 15% decline in nitrogen mining and water use, and almost 20% reduction in GHG emission intensity. This presents opportunities to reduce livestock numbers, freeing up land for food or cash crops, reforestation, or conservation efforts. To achieve sustainable farming in Ethiopia, substantial changes in livestock and land management are imperative. Transitioning to more intensive feeding systems such as cut-and-carry forage production of integrated grass-legume mixes or improved forage rotations with food crops could be crucial. However, further research is needed to assess gendered labour and decisionmaking implications.

Keywords: Crop-livestock systems, ex-ante assessment, grass-legume mixtures

Contact Address: An Notenbaert, The Alliance of Bioversity International & CIAT, 00100 Nairobi, Kenya, e-mail: a.notenbaert@cgiar.org

Unlocking farmer-preferred multipurpose forage mixtures: A tricot approach in Ethiopia

Kalkidan Ayele Mulatu¹, Kaue De Sous¹, Mohammed Ebrahim¹, Wuletawu Abera², Solomon Mwendia³, An Notenbaert³

¹*The Alliance of Bioversity International & CIAT, Ethiopia* ²*The Alliance of Bioversity International & CIAT, Ghana* ³*The Alliance of Bioversity International & CIAT, Kenya*

Farmers' insights are crucial for widespread adoption of new agricultural technologies. This study employed the Tricot approach, where farmers directly compared three sets of technologies under real-field conditions. The method, popular for food crops in small-scale farming, was adapted for forages in Ethiopia.

Across two regions with contrasting mid-altitude environments (Amhara and Sidama), we engaged 600 farmers in two cycles. The goal: identify a forage mixture offering both livestock feed and land restoration benefits. Fourteen treatments were evaluated, including monoculture grass and legume varieties, as well as their mixtures. Through randomisation, each farmer received three treatments.

District agricultural officers were trained on managing each forage species (land preparation, weeding, harvesting) and using digital data collection tools. They then assisted farmers throughout the experiment. Farmers were encouraged to observe and record their experiences throughout the establishment and harvesting phases. This allowed them to rank the varieties based on traits and performance and identify their preferences from most favourite to least favourite within their assigned set of three.

While preferences varied across regions, the overall favourite combination emerged as Panicum cv Mombasa, *Brachiaria* hybrid Cayman, Desmodium intortum, and *Stylosanthes Hamata*. Notably, soil cover and erosion reduction were key factors influencing this preference. The preference ranking likely reflects the most probable choices for adoption by livestock and forage producers in the study areas and potentially in similar environments.

The scaling of multipurpose forages and their mixtures could be linked to land restoration efforts at different scales to ensure availability of land to produce forages, especially through area closures and rehabilitation of degraded range lands. Improving national forage seed registration systems would be critical to ensure the availability of planting materials.

Keywords: Citizen-science, ethiopia, forages, mixtures, restoration, tricot

Contact Address: Kalkidan Ayele Mulatu, The Alliance of Bioversity International & CIAT, Gurdshola, Addis Ababa, Ethiopia, e-mail: k.mulatu@cgiar.org

Sustainability of innovation adoption under smallholder cattle production systems in Eastern Indonesia and Timor Leste

Dahlanuddin¹, Tanda Panjaitan², Yusuf Akhyar Sutaryono¹, Geoffry Fordyce³, Max Shelton³, Dennis P Poppi³

¹University of Mataram, Fac. of Animal Science; Dept. of Animal Nutrition, Indonesia ²National Research and Innovation Agency, Research Centre for Animal Husbandry, Indonesia

³University of Queensland, Animal Science, Australia

After more than 20 years of our collaborative research, several innovations have successfully improved productivity of cattle in the smallholder system in eastern Indonesia and Timor Leste. During 2004–2021, an integrated production system of Bali cattle (Bos javanicus) based on controlled natural mating, better feeding and early weaning was trialed in the west Nusa Tenggara region and successfully increased calving rate from 60 % to 85 %, reduced calf mortality from 15 % to 5 % and increased weaning weight from 70 to 90 kg. This proof of concept was successfully scaled out to 36 farmer groups in the region. However, wide adoption of this production model was not sustainable beyond the project life due to failure of the community to sustain best practices without external facilitation. In addition, subsequent government programmes and supports did not support a continuous adoption. Various successful trials on improved feeding systems based on introduced forages, crop residues and industrial byproducts, have not also been adopted widely. Learning from these outcomes, starting from 2011, a tree legume-based cattle fattening system was introduced. Two tree legumes; Sesbania grandiflora and Leucaena leucocephala have been widely adopted with different magnitudes. Sesbania adoption has been limited to southern part of Lombok Island where it suits best, while Leucaena have been adopted in much wider dry areas of Eastern Indonesia and Timor Leste. By 2022 it is estimated that at least 5000 farmers in eastern Indonesia and Timor Leste have adopted this leucaena based cattle fattening system. The key to the wide and sustainable adoption of leucaena based cattle fattening system are: the technology is simple but significantly increases cattle growth rate from 0.2 to 0.5 kg-1, farmers see the immediate financial benefit, leucaena is best suited to the dry areas, it does not require high inputs such as irrigation and fertilisers, it matches the local practice of cutting trees rather than cutting grasses, and leucaena can be harvested continuously for at least 25 years since establishment.

Keywords: Adoption, Bali cattle, cattle growth, smallholders

Contact Address: Dahlanuddin, University of Mataram, Fac. of Animal Science; Dept. of Animal Nutrition, Mataram, Indonesia, e-mail: dahlan.unram@gmail.com

Dynamic duo: Exploring mortality rate shock effects in integrated livestock models

Admasu Maruta, Sirak Bahta

International Livestock Research institute (ILRI), Policies, Institutions and Livelihoods (PIL) Program, Kenya

This paper explores the synergies between the Dynmod model and the multi-market partial equilibrium model (also known as SectorM), two crucial tools for understanding the dynamics of the livestock sector. Dynmod model excels in capturing intricate herd dynamics over time, representing factors such as offtake rate, mortality rate, parturition rate, age, sex, size, and various demographic attributes. However, Dynmod operates under the assumption of constant prices and economic variables during simulations, limiting its ability to incorporate the dynamic economic conditions that characterise the real-world livestock sector. In contrast, SectorM is proficient in capturing economic factors, considering prices and other variables as endogenous, allowing them to vary over time based on influencing factors. While SectorM excels in economic intricacies, its representation of herd dynamics and demographic factors is comparatively less detailed than Dynmod. Recognizing the complementary strengths of these models, this research bridges the gap by linking Dynmod and SectorM, using the General Algebraic Modelling System (GAMS) software and focusing on Tanzania's livestock sector as a case study. By doing so, the aim is to harness the detailed herd dynamics of Dynmod alongside the economic adaptability of SectorM, creating a more comprehensive and realistic simulation of the livestock sector. This approach addresses the weaknesses of each model with the strengths of the other, enriching the simulation results and providing a more accurate depiction of the dynamic interplay between herd dynamics and economic factors. To evaluate the linkage's efficiency and simulation accuracy, we introduce a shock related to animal mortality. The rationale for considering this shock is that it significantly influences livestock sector resilience, impacting production outcomes, market dynamics, and farmers' livelihoods. High mortality rates pose economic losses and food security risks at household and national levels, reflecting underlying health issues within livestock populations. By integrating animal mortality scenarios, our study aims to reveal their implications on Tanzania's livestock production, trade, and livelihoods. Understanding mortality rate effects is crucial for policymakers and stakeholders to devise interventions enhancing sector resilience and farmer welfare.

Keywords: Animal mortality, dynmod, multi-market partial equilibrium

Contact Address: Admasu Maruta, International Livestock Research institute (ILRI), Policies, Institutions and Livelihoods (PIL) Program, ILRI Kenya, 30709 Nairobi, Kenya, e-mail: am.asfaw@cgiar.org

Feasibility study: Black soldier fly production for animal feed in Ethiopia

Mathieu Chaix-Bar¹, Oghaiki Asaah Ndambi², Somaya Naser EL Deen²

¹TRAIDE Foundation, Ethiopia

²Wageningen University & Research, Animal Science Group, The Netherlands

Effective organic waste management, affordable animal feed and fertiliser are three major challenges that permeate across rural and urban Ethiopia. The tropical insect, black solder fly (BSF, *Hermetia illucens*), has demonstrated globally its potential to tackle some or all of these challenges sustainably.

The increase in both the human population and migration into urban areas of Ethiopia have led to an increase in waste production. On average, 60 % of the waste in and around urban areas is organic, BSF could play a significant role in reducing the total biomass generated and thus alleviate the pressure on landfills and municipalities whilst making urban areas more safe, environmentally resilient and attractive. Agroprocessing and agricultural waste are also promising substrates to rear BSF. Hotspots of potential project locations have been identified where there are favourable climatic conditions for BSF and value chain stakeholders are concentrated.

This feasibility study assesses the opportunities and challenges, at various scales, for the onset of this innovative industry in the country. It presents further the biotechnology to policymakers, professors and entrepreneurs, evaluates the different waste streams within different contexts, assesses the demand-driving factors for alternative ingredients for animal feed, presents two business cases to illustrate the potential of a BSF farm, and then elicits challenges to overcome and recommendations to undertake for smooth technology adoption and steady sector growth over the coming decade. A medium-scale BSF farm, close to an urban area or on the premises of an agro-processing company, has been shown to be logistically and financially viable. However, at current market prices, smallholder BSF production doesn't seem economically viable if used as a substitute for soybean meal; but it becomes viable when BSF substitutes fishmeal.

The demand for animal-sourced food has been increasing over the past decade, and so has the price of animal feed ingredients, particularly protein sources. The need for competitive alternative sources of protein for animal feed, and thus BSF, has been estimated and confirmed from recent market data and key personal communications. Interviews with key stakeholders on the issue of integrating BSF products into their operations have elicited encouraging responses.

Keywords: Alternative protein, organic fertiliser, waste management

Contact Address: Oghaiki Asaah Ndambi, Wageningen University & Research, Animal Science Group, Wageningen, The Netherlands, e-mail: asaah.ndambi@wur.nl

Economic impact of *Canavalia brasiliensis* hay supplementation in beef cattle farming in the Colombian Caribbean

John Jairo Junca Paredes¹, José Edwin Mojica Rodríguez², Edwin Castro Rincón², Mauricio Sotelo¹, Stefan Burkart¹

¹*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia* ²*AGROSAVIA, Research Group on Microbiology and Animal Nutrition in the Tropics, Colombia*

Improving cattle systems stands as a pivotal measure to increase the income and livelihoods of Colombia's most marginalised rural communities and to enhance environmental sustainability. The present case study focuses on providing an economic analysis of sustainable production alternatives for the traditional cattle system in the Caribbean region of Colombia, which is characterised by minimal investment in pastures and limited feed offer and diversity for cattle during the dry season. The system is typically reliant on monoculture pastures, specifically Bothriochloa pertusa (Colosuana grass) and extensive cattle ranching predominates, leading to agricultural frontier expansion. The intervention strategy targeted pasture improvement measures and a supplementation with hay from the legume *Canavalia brasiliensis* at varying inclusion levels (IL) of 0.5%, 1.0%, and 1.5% of dry matter according to the animal liveweight. The technical and productivity outcomes of these interventions proved positive, prompting an evaluation of their economic feasibility. Employing cash flow analysis, profitability metrics such as Net Present Value (NPV) and Internal Rate of Return (IRR) were calculated within a probabilistic framework, enhancing the robustness of estimates and highlighting key variables impacting economic gains. The findings demonstrate profitability across all production alternatives. Notably, profitability surged substantially from the traditional system, with the average IRR increasing from 10.19% to 16.74 %, 16.85 %, and 17.39 % for the three intervention scenarios, respectively. The most promising alternative is supplementation at the 1.5 % IL, where milk productivity accounted for 73.4% of profitability. Beyond enhancing productivity and mitigating environmental impacts, the integration of legumes helps in soil restoration and reduces the ecological footprint of cattle farming. The identified benefits of such technological change underscore the imperative of fostering the adoption of new practices among small-scale cattle farmers.

Keywords: Economic evaluation, environmental impact reduction, legumes, milk productivity

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Effects of a *Lactobacillus buchneri* inoculant on the fermentation profile, microbial counts, and aerobic stability of corn silage at different dry matter contents

ANDREAS MILIMONKA¹, THIAGO BERNARDES² ¹Addcon GmbH, Germany ²University of Lavras, Department of Animal Science, Brazil

With an increasing human population access to ruminant products is an important factor in global food supply, especially if ruminants use crops, not available for human nutrition. While ruminants contribute to climate change, climate change could also affect ruminant production. Growing forages under elevated temperature, drought or flood can induce stress responses and that could affect not just crop production but also feed availability from natural grasslands, and thereby nutritive value to ruminants. In addition, dairy cows should feed with high energy, nutrient rich roughage, because a high yielding caw is a climate saving cow by a lower CO_2 -equivalent output per milk and meat yield. The maize crop is an important crop because of combining high yields, high feed quality and a quite high water use efficacy. But due to the competition of maize in case of feed/food a strong focus on the reduction losses in silage production and during feed-out should be given.

The hypothesis of this study was that *Lactobacillus buchneri* based silage inoculants improve aerobic stability during feed-out, by modification of the fermentation profile during fermentation of a whole-plant corn crop.

The maize crop was harvested at two different harvest stages (29% and 38% DM content). At both DM levels the inoculated silages had been characterised by an elevated acetic acid content in the silage, slightly higher fermentation losses and a lower yeast count. As a result of the altered fermentation the aerobic stability was improved by 2.2 times. Caused by that the losses during aerobic exposure could be reduced from 7.5 to 2.8%, which saves a lot of CO_2 exhaustion.

Keywords: Aerobic stability, maize silage

Contact Address: Andreas Milimonka, Addcon GmbH, Parsevalstr 6, 06749 Bitterfeld, Germany, e-mail: andreas.milimonka@addcon.com

Assessment of oxalate content and their nutritive values of different Napier cultivars in Bangladesh

Muhammad Khairul Bashar^{1,2}, SM Jahangir Hossain², Panir Choudhury²,

Md. Tasmirul Islam², Md. Nazmul Huda², Shahrina Akter²

¹*University of Hohenheim, Dept. of Animal Nutrition, Germany*

²Bangladesh Livestock Research Institute (BLRI), Biotechnology, Bangladesh

Many farmers prefer Napier grass because of its excellent biomass yield, elevated crude protein concentration, and easy propagation. However, Napier grass contains oxalate, which is an anti-nutritional compound. The ongoing research work has identified the cutting-edge Napier cvs. that consistently preserve the standard oxalate content while achieving high biomass production and nutrient composition. The five Napier cultivars (Napier-3 (hybrid), Napier-4 (Vietnam), Napier-5 (salt-tolerant), Puckchong, and Napier colour) have been chosen for the purpose of quantifying the oxalate content at intervals of 10, 20, 30, 40, and 50 days with two replications. The land was then divided into 10 equal plots of 4×4 m², separated by an alley of about 1.5 m. All agronomical practices, such as fertiliser doses (2:1:1; N: P: K), irrigation, and weeding, were the same. To follow the cutting intervals, the sample was collected for chemical analysis (DM, CP, ADF, and NDF) at the animal nutrition laboratory of Bangladesh Livestock Research Institute (BLRI) and also determined the oxalate content to follow Martz FA et al., 1990 protocol at the BCSIR lab. After a 30-day period, Napier-3 exhibited a 1.55 % oxalate production rate, with CP and ADF levels of 18.5 % and 32.0 %, respectively. This stage proved to be the most effective in reducing oxalate content (below 2% for ruminant animals) while maximising nutritional levels. Regarding Napier-5 and Pakchon grass, when 20 days old, they showed encouraging outcomes in terms of elevating CP levels (19.5% and 20.5%, respectively) and reducing ADF (30.5% and 31.0%, respectively) and oxalate content (1.27% and 1.14%, respectively). There was no notable interaction between Napier-4 and Napier colour. In conclusion, the Napier cultivars were graded according to their high nutrient and low oxalate levels: Pakchon> Napier-5> Napier-3>Napier colour> Napier-4.

Keywords: Napier cultivars, nutritive value, oxalate

Contact Address: Muhammad Khairul Bashar, University of Hohenheim, Dept. of Animal Nutrition, Wolff-Str. 10, 70599 Stuttgart, Germany, e-mail: kbashar20@yahoo.com

Salient considerations to address forage seeds access and use in eastern Africa

PETERS MICHAEL¹, STEFAN BURKART², AN NOTENBAERT¹, MICHAEL PETERS¹ ¹The Alliance of Bioversity International & CIAT, Kenya ²The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

While the primary obstacles to enhancing ruminant productivity in eastern Africa are well-documented, practical measures to address them are imperative. In this study, we focused on enhancing access to forage seeds for cultivation in cattle systems in several eastern African countries, namely Ethiopia, Tanzania, Kenya, Uganda, Rwanda, and Burundi. Drawing from existing literature, we examined factors such as ruminant population, feed dry matter deficits, and governmental priorities concerning cattle. The lack of access to forage seeds, coupled with a reluctance to invest in what is perceived as expensive elite improved forages, poses a significant challenge. Many farmers rely on vegetative planting materials, often utilising outdated improved materials that have not been adequately maintained for purity. Our analysis indicates a pressing need to transition to recently improved materials through rigorous selection and breeding processes to ensure sustained quality. To address the perceived high cost of seeds, there is a critical need to explore domestic seed production within the continent rather than relying on imports, which incur additional transport costs and other logistic and administrative burdens, such as complex variety registration processes. Given the nascent stage of the forage seed market in Africa, coordinated seed production efforts targeting a pooled market across multiple countries would be more economically viable than individual national initiatives. The development of such market would help fostering adoption levels of improved forages and promises a triple-win scenario, offering increased productivity, environmental benefits (including reduced methane production intensity), and alignment with the regional governments' ambitious agendas for the sector.

Keywords: Eastern Africa, forage seed, ruminant productivity

Contact Address: Peters Michael, The Alliance of Bioversity International & CIAT, 823-00621 Nairobi, Kenya, e-mail: m.peters-ciat@cgiar.org

Impacts of *Urochloa* hybrid forage seed adoption in the global tropics 2001–2022

Stefan Burkart¹, Rosa Noemi Jauregui¹, An Notenbaert², Mary Atieno³, Michael Peters²

¹*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia* ²*The Alliance of Bioversity International & CIAT, Kenya*

³*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Vietnam*

Despite the economic and social importance of cattle farming in the tropics, it is being questioned for the environmental impacts it can generate. Likewise, cattle farmers are affected by climate change, increasing vulnerability and putting food security at risk. The cattle sector is thus in a difficult position and at the centre of the political debate on how to sustainably increase productivity while reducing potential negative impacts on the environment. One of the strategies in that regard is the development of improved feeding strategies. Against this background, the International Center for Tropical Agriculture (CIAT) and its partners have launched a forage breeding programme in 1987, focused on the development of interspecific *Urochloa* (syn. *Brachiaria*) hybrids. The first hybrid was released in 2001 by Grupo Papalotla, a seed company from Mexico, and since then, hybrid adoption has happened in >70 countries. The impacts this adoption has generated over time are, however, yet largely unknown. Based on seed sales data, global databases, national statistics, grey literature, media, and expert consultations, this study analyses these impacts regarding 4 dimensions: land use, social, economic, and environmental impacts. The results indicate an adoption between 2001 and 2022 by >1.4 million farmers on >1.6 million ha, which has benefitted almost 11 million people. By 2031, this adoption will have generated an economic value of US\$ 10–17 billion. Likewise, it is estimated that the adoption has caused a reduction in GHG emissions of 23–54 megatons CO₂eq. in the Americas alone. Most of the impacts have happened in Latin America, but Africa and Asia are emerging markets with large untapped potential for further adoption and seed market development, income generation and diversification, and livelihood improvements of the most vulnerable parts of the population.

Keywords: Forage hybrids, impact analysis, improved forages, seed systems, sustainable intensification, technology adoption

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Evaluation of improved forages for improved livestock nutrition and productivity in the northwest highlands of Vietnam

Trong Hieu Do 1, Hang Thi Dao 2, Thi Bich Ngoc Tran 3, Michael Peters 4, Mary Atieno 2

¹Northern Mountainous Agriculture & Forestry Science Institute, Vietnam ²The Alliance of Bioversity International & CIAT, Tropical Forage Program, Vietnam ³National Institute of Animal Science, Vietnam

⁴The Alliance of Bioversity International & CIAT, Trop. Forages Program, Kenya

Livestock production is an integral part of farmers' livelihoods in the Northwest Highlands (NWH) of Vietnam. Son La province in NWH has implemented new policies and programmes to support the expansion of livestock, aiming to increase cattle productivity. However, farmers have limited knowledge on suitable forage types, management practices, and utilisation that lead to low productivity. Cattle are fed using native pastures, crop residues, and grazing on communal land and forests. Moreover, this region faces feed-related challenges such as low-quality forages (mainly Napier), feedstuff and winter feed shortage. To address these challenges, development partners in Vietnam, in the frame of the CGIAR initiative on Sustainable Animal Productivity, are piloting a pipeline of innovations including feeds and forages interventions. The objective of this study is to evaluate the potential of improved forages well-suited to the local soil, climate, and farming conditions, in addressing winter feed shortage and ensuring year-round feed availability. Eight improved forage varieties including Mun River Guinea, Mombasa Guinea, Mulato II, Green Elephant grass (GE), Napier grass (VA06), biomass maize (BM), Ubon Stylo and rice bean were evaluated through demo farms and farmer-led trials, and capacity building of farmers and local stakeholders on forage establishment, management, and utilisation. Various plant growth parameters, including biomass yields, were evaluated to assess adaptation during both the wet and dry seasons. Initial results reported that GE, BM, VA06, Mun River Guinea and Mombasa Guinea exhibited robust growth and yield (35 – 48 t ha⁻¹) during the rainy season. In the dry season, GE, Mulato II and Mun River Guinea recorded the highest biomass yield, despite a significant decline in yield as compared to the rainy season. These varieties also received positive feedback from both local partners and farmers. Among legumes, rice bean reported better growth and yield better than Ubon Stylo. However, stylo is a perennial crop which can offer long-term usability despite slower growth. The results show that improved forages are crucial to combat feed shortages and have the potential to enhance livestock productivity and efficiency in NWH, laying a good foundation for scaling to contribute to sustainable livestock development in the region.

Keywords: Dry season, feed, improved forages, livestock productivity

Contact Address: Hang Thi Dao, The Alliance of Bioversity International & CIAT, Tropical Forage Program, 2qxm+87r vien di truyen nong nghiep pham van dong Co nhuu tu liem, Hanoi, Vietnam, e-mail: h.dao@cgiar.org

Participatory forage evaluation for integration in mixed crop-livestock-tree systems in Lao PDR: An entry point for sustainable intensification

MARY ATIENO¹, SOUKSAMLANE KHAMPHOUMEE², MICHAEL PETERS³

¹*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Vietnam* ²*Livestock Research Center, National Agriculture and Forestry Institute, Lao PDR* ³*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Kenya*

In Lao PDR, smallholder farmers dominate agriculture and food production, mainly relying on rainfed, low-input crop and livestock production. Livestock production in Laos has notably increased in the past decade, with the country's cattle population growing from 1.7 million in 2012 to 2.3 million in 2021. This upward trend suggests a continuous rise in livestock numbers, aligning with the government's efforts to boost cattle production in response to the growing demand. However, despite smallholders being the main players in livestock production, inadequate feed quantity and quality pose a significant challenge, particularly in the dry season. Cattle are typically raised in extensive systems, relying on natural/naturalised pastures and low-quality forages as the primary feed source. To fully leverage the potential for the regional market and enhance smallholder livelihoods, addressing the issue of inadequate feed is crucial. In the frame of the CGIAR initiative on Mixed Farming Systems, a farmer participatory evaluation of forages was conducted in different parts of Laos, to provide farmers with forage options for integration into their farming systems. Demonstrations farms with thirteen forages, including eight grasses and five legumes, were established in Mok (North), Naxathong (Central), and Thateng (South) districts. Farmer field days were held with a total of 90 farmers, 30 from each district, who assessed forage growth, biomass production, and pest/disease incidence using a scale of 1 to 4. Farmers across three districts reported an overall preference for forage grasses over legumes, likely due to the higher biomass of the grasses. The most preferred grasses were Urochloa hybrids for their fast growth, high biomass production in both the wet and dry seasons. For the legumes, Ubon stylo was scored as the highest in terms of farmers' preferences. Although the evaluation is ongoing, initial results indicate the potential for selecting and integrating high-quality and resilient forage materials into farming systems to enhance livestock productivity, improve livelihoods, and offer environmental benefits. Moreover, establishment of seed systems is crucial to enable farmers to access their preferred varieties. Collaboration with national and local partners, the private sector, and farmers is essential to ensure sustainability of the seed supply chain.

Keywords: Feed, forages, livestock, participatory evaluation

Contact Address: Mary Atieno, The Alliance of Bioversity International & CIAT, Trop. Forages Program, Hanoi, Vietnam, e-mail: mary.otieno@cgiar.org

Fermentation products, nutritive value, and aerobic stability of pineapple by-product silage prepared using *Lactobacillus buchneri*

Rona Cathrina Lizardo¹, Khaterine Salazar-Cubillas¹, Jacobo Arango², Uta Dickhöfer¹

¹*Christian Albrechts University of Kiel, Inst. of Animal Nutr. and Physiology, Germany* ²*The Alliance of Bioversity International & CIAT, Colombia*

Due to high moisture content (> 80% fresh matter), pineapple by-products were commonly ensiled with absorbents and homofermentative lactic acid bacteria (LAB) to preserve the nutrients and prevent mal-fermentation. Nevertheless, aerobic stability remains an issue, which could be addressed by introducing heterofermentative LAB, such as Lactobacillus buchneri. Thus, the current study was conducted 1) to determine the effect of L. buchneri on the chemical composition, energy value, digestibility, fermentation products, and aerobic stability and 2) to identify the correct ensiling time for pineapple byproduct silage. A proportion of 4 crowns : 1 peel and pulp was mixed, and applied with distilled water (T1; control); inoculated with L. buchneri (Magniva Steel, Lallemand; T2); and inoculated with L. buchneri and homofermentative bacteria with enzymes (Magniva Classic, Lallemand; T3). Four replicates per treatment were prepared using vacuum-sealed bags and ensiled for 30, 60, and 75 days. After opening the silage, chemical composition, energy value, digestibility, fermentation products, and aerobic stability were determined. The addition of inoculants did not affect the chemical compositions, energy value, and digestibility (p > 0.05), but a significant effect was observed with the ensiling length (p < 0.01). A significant decline in the pH level from 4.53 to a range between 3.42 and 3.46 after 7 days of ensiling was observed in the control and inoculated silages (p < 0.01), while an increase in the ammonia-nitrogen concentration was found in the inoculated silages from 0.21 to 0.32 g kg⁻¹ nitrogen at the end of the ensiling. A greater concentration of acetic (4.56 to 5.13 g kg⁻¹ DM) and propionic acid (3.09 to 3.97 g kg⁻¹ was detected in inoculated silages after 30 days of ensiling (p < 0.01), resulting in a lower lactic-to-acetic acid ratio (2.93 to 3.21), and improved aerobic stability (p < 0.01). Hence, inoculants may be unnecessary for preserving the nutritional components of pineapple by-products during ensiling. However, they notably improve the aerobic stability of silage (T1: 18–22 hours), especially with ensiling periods of at least 75 days (T2 and T3: 26–74 hours).

Keywords: Acetic acid, ensiling, epiphytic LAB, lactic-to-acetic acid ratio

Contact Address: Rona Cathrina Lizardo, Christian Albrechts University of Kiel, Inst. of Animal Nutr. and Physiology, 24118 Kiel, Germany, e-mail: stu236250@mail.uni-kiel.de
Evaluation of nutritional composition of tropical forages and relationship between fibre fraction and fibre digestibility

Risma Rizkia Nurdianti¹, Uta Dickhöfer², Joaquin Miguel Castro-Montoya³

¹University of Hohenheim, Animal Nutrition and Rangeland Management in the Tropics and Subtropics, Germany

²Christian-Albrechts-Universität zu Kiel, Inst. of Animal Nutrition and Physiology, Germany

³Universidad de El Salvador, Ciencias Agroalimentarias y Ambientales, El Salvador

The study aimed at evaluating the nutritional composition of tropical forage legumes (TFL) and the relationship of nutritional composition between fibre fraction and fibre digestibility, and compared it with tropical grasses (TG). Samples of 22 TFL and 11 TG were used. Proximate nutrient and fibre fractions were analysed. Undigested neutral detergent fibre (uNDF240) and potentially digestible neutral detergent fibre (pdNDF) concentrations and its proportion of total ash-corrected neutral detergent fibre (aNDFom) were determined in triplicate in two 240-h in vitro incubations using the modified Tilley and Terry technique. Data were analysed using SAS (V9.4, SAS Institute Inc., Cary, NC, USA). Pearson correlations and multiple linear regressions were determined using CORR and GLM procedures, respectively. The TFL had lower aNDFom, acid detergent fibre (ADF), and pdNDF concentrations, but had greater crude protein (CP), lignin, and uNDF240 concentrations compared to TG. The CP concentrations ranged from 149 to 251 g kg⁻¹ DM (TFL) and from 43 to 121 g kg⁻¹ DM (TG). The aNDFom concentrations ranged from 219 to 492 g kg⁻¹ DM (TFL) and from 418 to 631 g kg⁻¹ DM (TG). The uNDF240 concentrations ranged from 113 to 376 g kg⁻¹ DM (TFL) and from 125 to 308 g kg⁻¹ DM (TG). The pdNDF concentrations ranged from 75 to 216 g kg⁻¹ DM (TFL) and from 107 to 473 g kg⁻¹ DM (TG). Meanwhile, fibre digestibility ranged from 0.197 to 0.563 (TFL) and from 0.403 to 0.791 (TG). In TFL and TG, uNDF240 concentration correlated positively with aNDFom, ADF, and lignin concentrations. In TFL, fibre digestibility correlated negatively with aNDFom, ADF, and lignin concentrations. Meanwhile, only ADF and Lignin concentrations correlated negatively with fibre digestibility in TG. According to multiple linear regressions, uNDF240 concentration were related to aNDFom and lignin concentrations in TFL (p < 0.001) as well as to CP and lignin concentrations in TG (p < 0.001). In conclusion, fibre digestibility is related to aNDFom and lignin concentrations in TFL and to CP and lignin concentrations in TG. However, further research with a greater number of samples is needed to better define the relationship between proximate nutrient and fibre concentrations and fibre digestibility.

Keywords: Fibre digestibility, fibre fraction, forage legumes, grasses, ruminant nutrition

Contact Address: Risma Rizkia Nurdianti, University of Hohenheim, Animal Nutrition and Rangeland Management in the Tropics and Subtropics, Fruwirthstraße 31, 70599 Stuttgart, Germany, e-mail: risma_rizkia.nurdianti@uni-hohenheim.de

70 years of small ruminant research in Fiji: Review and current challenges

Romana Roschinsky, Tiago Alves Correa Carvalho da Silva, Frances Cowley

University of New England, School of Environmental and Rural Science, Australia

Sheep and goats have been produced in Fiji from as early as the 1840s and the country currently has the largest small ruminant production of all Pacific Island Countries. The first local research on small ruminants started in the 1950s. Over the decades the small ruminant production systems have been influenced by numerous challenges but remained an integral part of agricultural production systems in Fiji.

A database search was performed to better understand technologies tested and developed in local small ruminant research activities. Historic literature reviews and additional grey literature were considered additionally. The available published literature was systematically reviewed identifying technologies that have been adopted and persisted over time. Factors fostering or constraining their adoption were assessed. In addition, several key informant interviews revealed current challenges and developments of small ruminant research, and extension, in Fiji.

Four main drivers of the institutional environment for small ruminant research in Fiji have been identified. Among them, the Ministry of Agriculture of Fiji has traditionally been a proponent of small ruminant research to this day. Its efficiency in delivering research outcomes has fluctuated greatly over time.

Results revealed that key production system aspects have also been the focal areas of small ruminant research in Fiji with a strong focus on gastro-intestinal parasite management, breeding and forage development. The development of the Fiji Fantastic sheep breed has been a concerted success of the research and extension system and remains of great importance.

Conclusions from the literature review and key informant interviews include that many of the current challenges have remained unchanged since the beginning of small ruminant production in Fiji. The government is trying to find new ways to support the development of the local small ruminant sector. An aging farming population, the status of small ruminant production compared to other agricultural activities, low accessibility of small ruminant technologies and traditional land lease systems remain substantial impediments.

Keywords: Adoption, Fiji, goats, literature review, sheep, small ruminants

Contact Address: Romana Roschinsky, University of New England, School of Environmental and Rural Science, Elm Avenue, NSW 2351 Armidale, Australia, e-mail: rroschin@une.edu.au

Adoption factors of forage innovations in cattle production systems in the northwest highlands of Vietnam

Aura Bravo¹, Mary Atieno², Natalia Triana-Angel¹, Hang Thi Dao², Xuan Thao Hoang³, Thi Bich Ngoc Tran⁴, Michael Peters⁵, Thinh Nguyen⁶, Jesú's Fernando Florez¹, Stefan Burkart¹

¹The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

²*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Vietnam*

³Northern Mountainous Agriculture and Forestry Institute, Vietnam

⁴National Institute of Animal Science, Vietnam

⁵*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Kenya* ⁶*International Livestock Research Institute (ILRI), Vietnam*

Winter feed shortage, poor quality of available feed resources, and limited knowledge of suitable forage types, management, and utilisation are some challenges faced by livestock producers in the Northwest Highlands (NWH) of Vietnam. Context-specific feeding intervention strategies were designed and implemented to address these issues in Son La province, NWH. These are promoting the uptake of improved forage varieties (grasses and legumes) and capacity building on animal nutrition, including feed processing and preservation, and feeding regimens for cattle and pigs, respectively. Initial results show the potential of feed and forage technologies in improving livestock productivity in the region. This study aims at identifying the inhibiting and promoting adoption factors of seven improved forage technologies in the Chieng Luong and Chieng Chung communes, Mai Son District, Son La Province. A qualitative approach is chosen to fathom out the determinants of farmers' individual decisions when adopting these innovations for sustainable livestock production. The categories evaluated are based on the framework proposed by Ndah et al. (2022): 1) the individual characteristics predisposing to the acceptance or rejection of the technology; 2) attributes, knowledge, and challenges of technology use (known or perceived); and 3) contextual characteristics that create an enabling environment to stimulate adoption. Key informant interviews and focus group discussions will be conducted with cattle farmers (adopters and non-adopters, men and women) and other actors from the cattle value chain. The expected results will contribute to the efforts underway for designing integrated models for the delivery, adoption, and scaling of such technologies and knowledge in Vietnam, and give insights for scaling across the Southeast Asian region.

Keywords: Climate change, feed innovations, forages, livestock

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

From rural to urban: Exploring livestock farming practices in urbanizing landscapes

DAGMAR BRAAMHAAR, SIMON OOSTING, JAN VAN DER LEE Wageningen University & Research, Dept. of Animal Sciences, The Netherlands

Urbanisation in Kenya has surged in recent years, reshaping the agricultural landscape, and impacting livestock farming practices. This study focused on the county Nakuru, a region characterised by its fertile soils and increasing urbanisation due to its strategic location along the Nairobi-Eldoret Highway. This study investigated the spatial dynamics of livestock production systems across urban, peri-urban, and rural areas in Nakuru County, to assess the impact of urbanisation on livestock farming system development. Via stratified sampling, we examined farm size, herd size and -diversity, feeding methodologies, manure management, and market access at 241 farms across four sub-counties (i.e. Nakuru East, Njoro, Kuresoi North and Naivasha). In urban areas of Nakuru East, land scarcity led to limited space for forage production. The other areas prioritised land use for crop production over that for forage production for their livestock. The number of dairy cattle, dairy goats and chickens per farm did not differ among locations and were not significantly correlated to land size with on average 4.6 dairy cattle, 6.2 dairy goats, and 49.1 chickens for farms having that species. Specialized chicken farms were mainly observed in urban Nakuru East. The stocking rate was highest in the urban location (average 41.8 TLU ha⁻¹), but stocking rates were also high $(> 6 \text{ TLU ha}^{-1})$ in the peri-urban and rural areas, explaining the overall dependency on feed purchases. Agricultural supply stores were present at all locations, creating the opportunity for feed and other input purchases. Peri-urban and rural farms relied more on compound feeds, while urban farms incorporated specific energy and protein ingredients into their livestock diets. Manure management practices only differed slightly, with urban areas sometimes facing challenges of excess manure due to limited land. Overall, our research reveals that urbanisation is reshaping livestock farming practices across urban to rural locations. A shift is observed towards more intensive and market-oriented farming, while efforts are made to maintain resilience through the retention of diverse animal species and crops. Understanding these dynamics between urbanisation and livestock farming practices is crucial for developing sustainable agricultural production and marketing strategies that can accommodate the changing landscape of urbanizing areas.

Keywords: Feeding management, manure, spatial dynamics

Contact Address: Dagmar Braamhaar, Wageningen University & Research, Dept. of Animal Sciences, De Elst 1, 6708 WD Wageningen, The Netherlands, e-mail: dagmar.braamhaar@wur.nl

Determination of dietary regimen of *Moringa oleifera* leaves on selected blood constituents, productive traits, reproductive performance in Nubian goat

Faisal Ahmed 1 , Nahla Elhassan 2

¹University of Khartoum, Dept. of Reproduction and Obstetrics, Sudan ²University of Khartoum, Dept. Animal Nutrition, Sudan

The main objectives of the current study were to assess the influence of *Moringa* oleifera leaves (MOL) as a supplementary feeding regimen on selected blood Serum constituents, lactation and reproductive performances of Sudanese Nubian goats. Twenty apparently healthy, sexually mature (3 – 5 years old) multiparous Nanny goats of fair body condition score (BCS) were selected from a herd of 100 Nubian goats. The animals were allocated into 4 feeding levels groups (5 each) according to MOL supplementation. Group A (20%), group B (40%), group C (60%) of MOL, and group D (0%) left as control. The results obtained indicated no significant increase in blood serum levels of albumin, total proteins (TP), Ca, P, Mg, K, Fe, and Zn but there was a significant increase in the blood serum Na and Cu in supplemented groups compared to the control group. There was no significant difference observed in milk composition due to MOL supplementation. Nevertheless, milk yield was increased significantly (p < 0.05) in groups C and B compared to groups A and D. The ovarian response showed a significant difference (p < 0.05) in groups A and B (100%) compared to group C (80%) and group D (60%). In conclusion, the current study revealed that, Moringa oleifera leaves could be used for the improvement of the livestock production system of small ruminants without any adverse effect on the blood serum traits and reproductive performance at 20% and 40% diet inclusion levels.

Keywords: Dietary supplementation, Nubian goats, *Moringa oleifera*, reproductive performance

Contact Address: Nahla Elhassan, University of Khartoum, Dept. Animal Nutrition, Omdurman Athora Alhara 17, 11111 Khartoum, Sudan, e-mail: nahlavetxxx@gmail.com

Potential options to sustainably intensify mixed crop-ruminant systems in northern Ghana

Elizabeth Yeboah 1 , Terry Ansah 2 , Eva Schlecht 1 , Christian Bateki Adjogo 1

¹University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany

²University for Development Studies, Animal Science Department, Ghana

Northern Ghana is home to 70% of Ghana's ruminant livestock, kept in extensive mixed crop-ruminant (MCR) systems characterised by low performance. Using a two-stage approach, we assessed the suitability of strategies reported in literature for sustainably intensifying these MCR farms. First, we employed a semi-quantitative questionnaire and interviewed 134 MCR farmers identified by snowball sampling. Questions addressed household characteristics, husbandry practices, feed resource use, land accessibility, and challenges faced. Second, an online literature search identified published papers which recommended strategies to sustainably intensify MCR farms. A strategy was considered relevant if its implementation can be handled by farmers themselves. Interviewed MCR households had nine members on average, most of whom lacked formal education. They kept one or more livestock species (cattle, sheep, and goats), and cropped about 3.8 ha of farmland. Feed resources used in the dry season included crop residues from cereals, legumes, and tuber crops, and tree/shrub leaves, while depending mainly on local pastures in the rainy season. The main constraints to livestock production were feed and water scarcity during the dry season, high cost of supplementary feed and veterinary services, animal diseases, and animal theft. Our literature review suggests that adopting legume-cereal intercropping could increase biomass available for ration supplementation in the dry season. Planting multipurpose trees on-farm could supply high quality fodder for strategic feeding and treatment of gastrointestinal parasites. MCR farmers could come together within communities to organise animal health care, thereby reducing costs while increasing accessibility. We note that these strategies must be adjusted to on-farm realities to enhance their adoptability. For example, MCR farmers face the dilemma of whether to leave crop residues on fields to improve soils or to feed them to their animals. Combining the latter strategy with corralling animals on fields for a defined time may be a good compromise to ensure that nutrients are partly returned to each field via manure. Our further research will quantify year-round feeding practices to co-develop supplementation strategies that increase production of MCR systems in northern Ghana, based on a smart combination of local resources and innovative modifications to current practice.

Keywords: Mixed crop-ruminant systems, supplement feeding

Contact Address: Christian Bateki Adjogo, University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: christian.bateki@uni-kassel.de

Biomass yield and nutritive value of pigeon pea (*Cajanus cajan*) forage as affected by the coppicing regime and spatiotemporal storage

Mary Danse Salifu¹, Emmanuel Tenakwa¹, Shadrack Cudjoe¹, Zibilim Imoro², Christian Bateki Adjogo³, Terry Ansah¹

¹University for Development Studies, Animal Science, Ghana

²University for Development Studies, Biodiversity Conserv. and Management, Ghana

³University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany

Limited feed availability and quality are major factors hampering livestock productivity in pasture-based livestock systems in West Africa. As such, continuous efforts are being made to identify plant species with high forage yields and nutritive value to bridge the long dry seasons in the sub-region. The present study evaluated the effect of three coppicing regimes (i.e., 0%, 25% and 50% of branches coppiced) on forage and grain yield of pigeon pea, and the spatiotemporal storage effects on its nutritive value. The coppicing regimes were imposed on pigeon pea plants 12 weeks post-planting in a randomised complete block design over two years. At maturity (20 weeks post-planting), the grain and forage were harvested and weighed. The harvested forage was packed into sacks and preserved over a six-month period (November 2021 – April 2022) in three locations (i.e., storeroom, roof-top and tree fork), followed by chemical analysis. Over the two years, there was no significant difference in biomass yield at 20 weeks. The highest total biomass yield (pre-flowering + full maturity) was obtained at 50% coppicing in the first and second years while producing the highest grain yield in the first year. The lowest biomass yield was recorded in the 0% coppicing. In terms of nutritive value, the highest loss (-27%) in crude protein (CP) was observed in forage stored on tree forks, while the lowest (-15%) occurred in roof-top stored forages. In terms of the estimated metabolisable energy, a decrease was observed only in room-stored forages (-5.1%), while an increase was observed for the other two storage options, with the highest observed in tree fork storage (+4.9). Therefore, harvesting 50% of pigeon pea forage 12 weeks postplanting can promote forage biomass yield at full maturity. Our study suggests that storing pigeon pea forage on tree forks is the best option to preserve its nutritional quality over long periods of time.

Keywords: Coppicing regimes, forage storage, pigeon pea, ruminants, West Africa

Contact Address: Terry Ansah, University for Development Studies, Animal Science, Tamale, Ghana, e-mail: tansah@uds.edu.gh

Cattle corralling strategies for soil management in northern Benin: Benefits, constraints, and determinants

Awouminassi Marcellin Atakoun¹, Rodrigue V. Cao Diogo², Pierre Gbenoukpo Tovihoudji³, Nicolas Kyei-Bafour⁴, Boateng Kyereh⁵

¹*Kwame Nkrumah University of Science and Technology, Dept. of Civil Engineering, Ghana*

²*University of Parakou, Dept. of Sci. and Techn. of Animal Prod. and Fisheries, Benin* ³*University of Parakou, Dept. of Crop Production, Benin*

⁴*Kwame Nkrumah University of Science and Technology, Dept. of Agricultural Engineering, Ghana*

⁵*Kwame Nkrumah University of Science and Technology, Dept. of Silviculture and Forest Management, Ghana*

Developing integrated systems to manage soil fertility in the context of climate change has become a priority for our generation. This study examined the benefits, constraints, and factors that determine the adoption of cattle corralling practices in maizebased farming systems. The study answers the following questions: (i) what sociodemographic factors determine the different cattle corralling types adoption in rural Northern Benin? and, (ii) how the benefits and constraints of cattle corralling practices are perceived among smallholder farmers? In this study, we employed surveys from 392 households of smallholder farmers across three agroecological zones of Northern Benin for data collection. The descriptive statistic, Factorial Analysis of Correspondence (FAC) followed by an Ascending Hierarchical Classification (AHC) was used to examine the cattle corralling typologies among the smallholder farmers. A binary logistic regression model was performed to investigate the drivers of adoption. The results show that cattle corralling is widely known (89%) and adopted (71%), but the factors viz. security (44%), water availability (33%), forage availability (27%), and cattle ownership (50%) are perceived as very constraining for cattle corralling practice. The FAC and AHC reveal three groups of cattle corralling practices across the study area: overnight-rotational continuous corralling (ORCC), discontinuous corralling (DC), and corralling contract (CC). The adoption of cattle corralling as soil fertility management practice depends mainly on the agroecological zone (p < 0.001), educational level (p < 0.001), ethnicity (p < 0.001), access to credit (p < 0.001), awareness of corralling (p < 0.001), access to extension services (< 0.001), distance fields-house (p < 0.001), breeding strategy (p < 0.001) and the production objective (p < 0.001). The paper contributes to an understanding of the different typologies of cattle corralling practices and highlights the various socioeconomic factors driving its adoption by smallholder farmers. This is crucial for the upscale cattle corralling practices in the face of climate change in Benin and West Africa.

Keywords: Crop-livestock integration, drivers, sustainable land management

Contact Address: Awouminassi Marcellin Atakoun, Kwame Nkrumah University of Science and Technology, Dept. of Civil Engineering, Kumasi, Ghana, e-mail: atakoun.a@edu.wascal.org

Rangeland, pastoralism, livestock, and GHG emissions

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Assessing Africa's environmental footprints: Unveiling cattle production variations across regions

Glarion Isiaho¹, Emmanuel Mwema¹, Rein van der Hoek², An Notenbaert¹, Ricardo Gonzalez-Quintero¹

¹*The Alliance of Bioversity International & CIAT, Tropical Forages, Kenya* ²*The Alliance of Bioversity International & CIAT, West Africa, Senegal*

The livestock industry in Africa has experienced significant expansion due to increased demand for meat, dairy, and associated products. Nevertheless, while striving to meet the increasing demand for meat and milk, African livestock production systems generate significant environmental impacts mainly due to their relatively low productivity. Several research initiatives have assessed the greenhouse gas (GHG) emission intensities, soil impacts, water consumption, and land usage of various livestock systems across multiple regions in Africa. Despite advancements, there are still gaps in the understanding of regional variation of GHG emissions, water footprint, land footprint, and their implications for livestock production systems in Africa, particularly when assessed in terms of intensity per unit product. These gaps are evident in the notable lack of comprehensive studies that consolidate all environmental footprints from the African cattle production sector. This study seeks to review the existing evidence of cattle production characteristics in various environmental domains, including GHG emissions, water usage, land use, soil degradation, and nitrogen balance. Input data collected from existing literature spanning from 2003 to 2023 divides Africa into five regions: Northern, Eastern, Western, Central, and Southern Africa. The analysis categorises the production systems of cattle into three types: intensive, semi-intensive, and extensive systems. Six bibliographic databases namely Science Direct, PubMed, Web of Science, Dimensions Research Scholar, Semantic, and Research Gate were accessed. 112 publications were selected from a pool of 158 papers retrieved, after screening titles and abstracts. The findings indicate that cattle systems in Africa exhibit a notably higher environmental impact from meat and milk production compared to both global and continental levels. This exerts significant pressure on environmental resources, potentially leading to long-term risks. Significantly, Southern Africa demonstrates superior performance compared to other regions on the continent. However, persistent challenges such as low feed quality and availability, lack of specialisation, and reliance on low-productive breeds remain. Implementing locally tailored measures is essential to address these issues.

Keywords: Cattle, GHG emission, land footprint, productivity, regions, water footprint

Contact Address: Ricardo Gonzalez-Quintero, The Alliance of Bioversity International & CIAT, Tropical Forages, Nairobi, Kenya, e-mail: r.gonzalez@cgiar.org

Cattle behaviour and herders' supportive strategies: A case study of mountain grazing in Kunene North, Namibia

Wilhelmina Nuule 1, Lilli Scheiterle 2, Brigitte Kaufmann 2

¹*German Institute for Tropical and Subtropical Agriculture (DITSL), Namibia* ²*German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*

Cattle grazing preferences and patterns play a central role in shaping both animal and rangeland health, with significant implications for livestock production and human livelihoods. Grazing efficiency depends on the complex dynamics between people, animals, and their environment. This interplay is critical for pastoral communities where resources are available for a limited time after erratic rains. Especially during the dry season, small pockets of resources in the landscape can be a critical source of fodder. The ability to climb mountains is a trait that can make a critical difference, especially in the dry season when pasture is mostly only available uphill.

However, our understanding of the multifaceted human-animal-environment relationships that underpin grazing practices remains limited. Therefore, this study aims to fill this knowledge gap by investigating the factors that influence cattle behaviour associated with mountain grazing in Kunene North, Namibia.

Data were collected through narrative and semi-structured interviews with Himba pastoralists over a period of 9 months.

The results show that Himba pastoralists select for certain traits, but also teach their animals new behaviours. Mountain climbing is one of them, it is influenced by breed, body condition, and climbing experience. Herders also use strategies to help and teach new cattle to climb. For example, they create a trail by removing rocks that some have learned to fear because of previous hoof injuries or place cattle dung along the ïmaginary pathleading up the mountain for the animals to follow. Himba pastoralists know how to effectively use the intra-individual variability of their livestock for cattle to learn from their peers, but also how to actively influence their grazing patterns, by teaching them new behaviours.

The results show the importance of human-animal-environment relationships in the ability to use rangeland resources. The skills and experience of the herders and their cattle are transforming inaccessible grazing areas into important resources for the sustainability of the pastoral system in the mountainous areas of northern Kunene.

Keywords: Himba, human-animal-environment interactions

Contact Address: Wilhelmina Nuule, German Institute for Tropical and Subtropical Agriculture (DITSL), 1284 Coetzee, Pionierspark, Windhoek, Namibia, e-mail: w.nuule@ditsl.org

A comparative analysis of rangeland governance among two pastoral communities of northern Kenya

MALIT YUSUF WAKO¹, HUSSEIN WARIO², LILLI SCHEITERLE¹, BRIGITTE KAUFMANN¹ ¹German Institute for Tropical and Subtropical Agriculture (DITSL), Germany ²Center for Research and Development in Drylands, Kenya

Rangelands which cover up to 43% of Africa, are an important resource in pastoral livestock production that supports the livelihoods of millions across the continent. Harnessing rangeland productivity requires intricate resource governance and livestock grazing management to regulate access and use of resources that are highly variable across space and time. While previously, the rangeland management system was based on community governance structures, currently, the systems have been disrupted by neglect of the sophisticated community governance structures, inappropriate institutional frameworks, and investments such as unplanned water developments by NGOs. In combination with prolonged droughts, these factors contribute to pasture loss and constraints on pastoral mobility patterns, affecting both rangelands and pastoral livestock productivity. Therefore, the objective of this study is to analyse the similarities and differences in rangeland governance structures and practices between the Rendille and Borana Pastoral communities of Marsabit County, Northern Kenya. Data was collected using a mixed-method approach including net maps, participatory community mapping, key informant interviews, and focus group discussions over a period of six months. Results of this study showed that among the two communities, elders are tasked with governing and managing resources. Among the Rendille, 'Eween' elders are the main decision-makers around seasonal utilisation patterns and allocation of resources to different livestock, and among the Borana, 'Jars dedha' elders are consulted in decision-making and solving disputes of resource use. While certain parallels exist in the governance structure between the two communities, differences were observed in the roles of community elders in resource management decision-making. The study found among the Rendille, elders preserved the consultative nature and centrality in resource governance, whereas among the Borana it was seen to be shifting from a consultative nature to individuality such as Chiefs taking up decision-making roles. Hence, this study highlights the changes taking place, how different communities respond to changes in rangeland governance systems over time, and how the roles in management and use of resources are shaped by change.

Keywords: Community-based natural resource management, Eastern Africa, pastoral livestock systems, rangeland utilisation

Contact Address: Malit Yusuf Wako, German Institute for Tropical and Subtropical Agriculture (DITSL), Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: wmaliti@gmail.com

Effect of sedentarisation on pastoral management in four Fulani villages in northern Benin

Sèwanou Frimence Allogbènou Tossou¹, Rodrigue V. Cao Diogo¹, Eva Schlecht²

¹University of Parakou, Dep. of Sci. and Techn. of Animal Prod. and Fisheries, Benin ²University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany

As cattle herd management practices change in the context of sedentarisation, this study, conducted within the DecLaRe project (https://www.uni-kassel.de/forschung/ declare/home), aimed to determine the impact on herd mobility in northern Benin. To do so, eighty cattlemen from four Fulani villages in the region of Parakou were interviewed individually using semi-structured questionnaires. Questions addressed socio-demographic household characteristics, herd size and structure, livestock management, and cropping practices. Livestock production systems were classified using categorical principal components analysis and two-step cluster analysis. Important distinguishing factors of the two main pastoral systems were geographic location, number of animals and livestock species kept, daily travel distance for grazing (0–10 km or 10–20 km), and ownership of fodder cultivation plots. Two levels of herd mobility were identified, namely (i) sedentary management (n=53, 66.3%), where herders graze their animals within a 10 km radius of their settlement and cultivate fodder, and (ii) semi-sedentary management (n=27, 33.7%), where herders keep only cattle and graze beyond their village territory. No significant difference was found (p = 0.09) in the number of cattle kept by sedentary (64 + 29.9) and semi-sedentary (55 + 27.5)herders. Semi-sedentary pastoralists migrate with part of their herd to the Kara region in northern Togo (n=10, 37%) or to the Gogounou forest area in northern Benin (n=17, 63%) to access vast grazing areas and water sources during the second half of the dry season until the beginning of the rainy season (March-May). These movements reduce grazing pressure on the pastures of their residential villages for approximately three months, ensuring better forage access for the remaining animals. Village-based land access or ownership rights enable sedentary pastoralists to cultivate Panicum maximum (n=35, 43.8%) for their sheep and cattle. However, the local land tenure system is challenged by competing land uses, land fragmentation, and cropland expansion. In particular, the latter two trends may restrict the mobility patterns of semi-sedentary herds in the future. To reduce grazing pressure on natural rangelands under such a scenario, forage cultivation and village-level rangeland management arrangements need to be established, expanded and secured by sedentary and semi-sedentary livestock keepers together.

Keywords: Forage cultivation, grazing lands, northern Benin, rangeland management, sedentarisation

Contact Address: Eva Schlecht, University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Steinstraße 19, 37213 Witzenhausen, Germany, e-mail: tropanimals@uni-kassel.de

Greenhouse gas emissions from traditional livestock enclosures in Kenya and options for mitigation

Sonja Leitner¹, Yuhao Zhu², Victoria Carbonell¹, Rangarirayi Lucia Mhindu³, Klaus Butterbach-Bahl⁴, Lutz Merbold⁵

¹International Livestock Research Institute (ILRI), Mazingira Centre, Kenya

²*Chinese Academy of Sciences, Inst. of Mountain Hazards and Environment, China*

³*Midlands State University, Dept. for Land and Water Resources Manag., Zimbabwe*

⁴Karlsruhe Institute of Technology (KIT), Inst. of Meteorology and Climate Research,

Atmospheric Environmental Research, Germany

⁵Agroscope, Research Division Agroecology and Environment, Switzerland

Livestock in semi-arid pastoral rangelands is often corralled overnight in traditional enclosures ("bomas" or "kraals") to protect them from theft and predators. Manure is usually not removed from bomas but is left to accumulate, building thick manure layers that are hotspots for greenhouse gas (GHG) emissions in the landscape. Here, we present a full year of measurements of manure CH₄ and N₂O emissions from cattle bomas in Kenya. We found that GHG flux rates from bomas were elevated by several orders of magnitude compared to background savannah fluxes, with mean fluxes of $325 \pm 11 \,\mu g \,N_2 O N \,m^{-2} \,h^{-1}$ and $3245 \pm 234 \,\mu g \,CH_4 - C \,m^{-2} \,h^{-1}$ for active bomas, and $\overline{610} \pm 186 \,\mu g \,N_2 O-N \,m^{-2} \,h^{-1}$ and $\overline{3127} \pm 1262 \,\mu g \,CH_4 - C \,m^{-2} \,h^{-1}$ for abandoned bomas, while surrounding savannah soils only emitted 2.5 \pm 2.2 μ g N₂O-N m⁻² h⁻¹ and 0.1 \pm 0.7 μ g CH₄-C m⁻² h⁻¹. At the farm scale, boma manure contributed little (2.2 %) to total CH_4 emissions, which were dominated by enteric CH_4 emissions (97.6%); but bomas were a substantial source for N₂O, contributing over 32 % to total N₂O emissions on the farm. Annual manure emission factors were 2.43 \pm 0.42 %N for N₂O and 0.49 \pm 0.07 %C for CH₄, which corresponds to 2.64 \pm 0.37 g CH₄ kg⁻¹ volatile solids (VS). However, boma emissions are currently not captured in IPCC inventories because there is no category for them, and countries do not collect activity data for this emissions source. This likely leads to an underestimation of livestock GHG emissions from pastoral rangelands in sub-Saharan Africa. To mitigate boma GHG emissions, we suggest that manure should be removed regularly, or bomas should be relocated every few days/weeks to prevent excessive manure build-up and redistribute nutrients across the landscape. Boma manure can be used as fertiliser to grow crops and livestock feeds, preventing nutrient mining and ensuring rangeland productivity and resilience.

Keywords: Boma, kraal, manure, methane, nitrous oxide

Contact Address: Sonja Leitner, International Livestock Research Institute (ILRI), Mazingira Centre, Kabete Campus, Old Naivasha Rd., 00100 Nairobi, Kenya, e-mail: s.leitner@cgiar.org

Integral valuation of ecosystem services and environmental benefits in livestock farming

Jesús Fernando Florez¹, Mounir Louhaichi², Yigezu Atnafe Yigezu², Abdrahmane Wane³, Abeyou Worqlul², Sawsan Hassan², Azaiez Ouled Belgacem², Danny Fernando Sandoval¹, Judith Kamoto⁴, An Notenbaert⁵, Stanley Ng'ang'a Karanja⁵, Stefan Burkart¹

¹*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia* ²*International Center for Agricultural Research in the Dry Areas (ICARDA), Tunisia*

³International Livestock Research Institute (ILRI), Kenya

⁴Lilongwe University of Agriculture and Natural Resources, Dept. of Forestry, Malawi ⁵The Alliance of Bioversity International & CIAT, Kenya

Socio-ecological systems are based on the perspective of humans in nature. Natural systems produce ecosystem services for human beings, while social systems intervene in natural systems with positive (environmental benefits) and negative externalities. Livestock production takes place in a natural ecosystem, with human intervention. Accordingly, in livestock farming there exist both ecosystem services and environmental benefits. Our objective is to identify the main ecosystem services and environmental benefits present in livestock farming and propose an integral valuation strategy. We conducted an extensive literature review, established a working group with experts from the field, and conducted applications of proposed methods in the field. Based on this, we identified and prioritised seven ecosystem services and three environmental benefits for valuation, namely, food service, feed service, carbon storage and sequestration, microclimatic regulation, soil fertility, habitat for species, aesthetic appreciation, methane emissions reduction, water footprint reduction, and land use reduction. Our integral valuation strategy consists of the implementation of three valuation methods, i.e., ecological valuation, economic valuation, and social valuation. Our main result is the design of ten integral valuation strategies ready to be piloted in the field. These strategies will be fundamental for the economic and environmental assessment of different interventions in livestock farming and will complement traditional costbenefit and financial viability analyses. We have currently implemented these strategies in three studies in Colombia to evaluate the reduction of methane emissions in silvopastoral systems with improved pastures and the reduction of the carbon footprint in meat and milk production. Our findings show favourable outcomes when the environmental values are captured. The integral value of ecosystem services and environmental benefits will provide crucial support for informed decision-making on specific restoration initiatives, considering the project's objectives and the potential return on investment.

Keywords: Ecosystem services, integral valuation, livestock farming, socioecological systems

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Challenges of camel milk production and marketing in pastoral setting of Oromia region, Ethiopia

 $Regina \ Roessler^1, Bekele \ Megersa^2, Nebyou \ Moje \ Hawas^2$

¹University of Kassel, Animal Husbandry in the Tropics and Subtropics, Germany ²Addis Ababa University, College of Veterinary Medicine and Agriculture, Dept. of Vet Microbiology, Immunology and Public Health, Ethiopia

In Ethiopia, arid and semi-arid lowlands are predominantly inhabited by agro-/pastoralists. The agro-/pastoral production systems are crucial for the livelihoods of over 12 million Ethiopians and contribute significantly to the national GDP through livestock rearing. Due to recurrent droughts, traditional cattle pastoralists have recently shifted their livestock to include camels because they are more drought-tolerant than cattle. Hitherto, there are limited or no published research on camel milk production/marketing and their potential role to sustainably manage degrading natural resources in Borana and Fentale areas located in two zones of Oromia regional state. In 2023, a baseline study was realised in Borana and Fentale areas with the objective to examine the major challenges of camel milk production and marketing and to identify associated pathways for future research in these areas. Camel herders were approached in individual interviews in Borana (n=30) and Fentale (n=23) areas in addition to three focus group discussions using structured questionnaires. Nine expert interviews and two feedback workshops were also conducted. According to the results, the main constraints affecting camel milk production were feed shortage due to expansion of cropland (Borana) and cutting of trees for feeding camels (Fentale), long distance to water sources (Fentale), diseases due to inadequate animal health services, shortage of camel vaccines and migration to tsetse fly infested areas (Borana), security problems due to armed conflicts (Fentale) and camel calf mortality. Furthermore, there was no well-developed and organised camel milk market in the two study areas, with shortage of permanent and protected marketplaces, shortage of cooling and processing facilities, inadequate transportation means, spoilage of milk (especially Borana), fluctuating prices (Borana), low demand for camel milk (Borana) and lack of milk testing. The channel of marketing is majorly to collectors, only a minor share directly sells to final consumers (especially Fentale) or dairy cooperatives. Hence, research is needed to solve feed problems of camels through improved feeding management and protection of fodder trees, improving health care and breeding management, establishing accessible veterinary care services for migrating camel herds, improving milk hygienic practices, developing organised markets chains and infrastructure, and establishing dairy cooperatives.

Keywords: Camels, Ethiopia, milk production, milk value chain

Contact Address: Regina Roeßler, University of Kassel, Animal Husbandry in the Tropics and Subtropics, Witzenhausen, Germany, e-mail: regina.roessler@uni-kassel.de

Managing emissions and nutrient losses from cattle manure through cascades with carbonized materials in Kenya

Ludy Keino¹, Yuhao Zhu², Dries Roobroeck³, Arusey Cheber⁴, Collins Oduor⁴, Ruth Njoroge⁵, Abigael Otinga⁵, Prasad Hendre¹, Sonja Leitner⁴

¹*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya*

²Chinese Academy of Sciences, Inst. of Mountain Hazards and Environment, China

³International Institute of Tropical Agriculture (IITA), Kenya

⁴International Livestock Research Institute (ILRI), Mazingira Centre, Kenya

⁵University of Eldoret, Soil Science, Kenya

Improved use of manure is key to sustainable intensification of livestock systems and agricultural production across Sub-Saharan Africa. Common manure storage practices in heaps without covering are fraught with greenhouse gas and NH₃ emissions which negatively impacts its climate footprint and fertiliser quality. Our research evaluates how amending manure with biochar (activated and non-activated) and charcoal at 10 % and 30 % influence GHG and NH₃ emissions, manure nutrient content and CH₄ and N₂O emissions factors (EFs). Incubations of freshly collected solid dung, excluding urine, were done for each treatment over 105 days under aerobic conditions. Cumulative CH₄ emissions from 10 % biochar (1.44 \pm 0.13 g C kg⁻¹ DW) and 30 % activated biochar (1.64+0.22 g C kg⁻¹ DW) were lower than emissions from control i.e. no amendment (2.40±0.34 g C kg⁻¹ DW). Cumulative N₂O emissions from 30 % non-activated biochar (11.1 \pm 1.62 mg N kg⁻¹) and 30 % activated biochar $(15.8+2.09 \text{ mg N kg}^{-1})$ were lower than the control $(27.2+2.94 \text{ mg N kg}^{-1})$. In addition, biochar (activated and non-activated) and 30% charcoal addition significantly reduced NH₃ cumulative emissions, with the 30% rates having lower NH₃ emissions than the 10% rates. It was found that 10% activated biochar and 10% charcoal treatments had higher NO₃ concentrations (+ 12 and + 3 μ g NO₃ N g⁻¹ DW respectively) than the control. The 10% non-activated biochar, 30% biochar and charcoal treatments had lower NH_{4}^{+} , NO_{3} , and total N compared to the control. The N losses as N_2O were higher in control (0.19±0.02%) than 30% biochar (0.07±0.01%), 30% activated biochar $(0.11\pm0.01\%)$ and 30% charcoal $(0.14\pm0.02\%)$. In terms of NH₃, control treatment also had higher losses compared to the 30% concentrations. Emission factors of CH₄ and N₂O for all biochar enriched manure treatment were lower than the IPCC default values for solid storage. This study illustrates the potential of biochar cascades in farming systems to improve management of GHG emissions and nutrient in manure, which should be further explored to assess its feasibility for smallholder farmers.

Keywords: Ammonia, biochar, charcoal, greenhouse gases, incubation studies, manure

Contact Address: Ludy Keino, The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), 30677 Un Avenue, 00100 Nairobi, Kenya, e-mail: l.keino@cifor-icraf.org

Rangeland rehabilitation as a tool for livestock management and disease prevention in Eastern Africa

Mascha Kaddori, Anja Beterams

Veterinaire Sans Frontiers Germany, One Health, Germany

Vétérinaires Sans Frontières Germany (VSFG) is a non-governmental organisation dedicated to improving animal health, food security, and the livelihoods of pastoralist communities in various regions in East Africa. Recognizing the intricate interplay between animal, human and environmental health, VSF Germany employs a holistic approach to address the multifaceted challenges faced by these communities.

The rehabilitation of rangelands in East Africa is crucial for the conservation of ecosystems and thus for the preservation of biodiversity and the safeguarding of local livelihoods. In that case, the link between livelihood sustainability, food security and animal health is complex as well as of central importance. The rangelands in this region face multiple challenges: overgrazing, deforestation, soil erosion, invasive species and the negative effects of climate change, especially droughts and desertification.

Diseases such as Peste des Petits Ruminants (PPR) pose a significant threat to food security through loss of production of meat and milk products, as the mortality of infected animals is high. It can therefore lead to migration, poverty, malnutrition, social insecurity and even conflicts that might escalate into wars. The FAO emphasises the urgency of eradicating PPR by 2030 and calls for an increase in funding to curb its spread. Similarly, anthrax, which is exacerbated by drought, poses a threat to both ruminants and humans. The transmission of Bacillus anthracis spores to livestock via the ingestion of contaminated grass due to contaminated soil means that the disease can be transmitted to humans via raw dairy products and meat.

To address these challenges, a holistic, interdisciplinary and multi-sectoral One Health approach that combines rangeland rehabilitation and sustainable livestock management with diversified agricultural practices and fisheries development are essential for resilient and thriving communities in East Africa. VSFG is already implementing this as part of projects with local communities in countries such as Sudan and Ethiopia, which are particularly affected by the consequences of climate change and armed conflicts, and thereby improves the lives for both animals and humans.

Keywords: Animal health, food safety, livelihoods, One Health

Contact Address: Anja Beterams, Veterinaire Sans Frontiers Germany, One Health, Marienstraße 19-20, 10117 Berlin, Germany, e-mail: anja.beterams@togev.de

Perception and adaptation of pastoralists to climate change in the central mountainous region of Pakistan

WAQAR UL HASSAN TAREEN, EVA SCHLECHT University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Germany

Similar to many other communities, the livelihoods of pastoralists in the central mountainous Koh-e-Suleiman Range of Pakistan (ranging from 500 to 3000 meters elevation) are threatened by recent extreme climate events. This study aimed to understand pastoralists' perceptions of climate change and adaptations they may already practice. In a mixed-methods approach, 199 individual interviews were combined with six focus group discussions with pastoralists from six tribes living at different altitudes in the Koh-e-Suleiman Range. Their responses were compared with real-time climate data collected over a seven-year period (2017–2023) from four flood automatic weather stations installed at different geographical locations in the study area.

About half of the respondents were practicing a sedentary lifestyle, while the others practised dry winter season transhumance with their animals. Households were characterised by a joint family system and comprised on average 14 members. Herd sizes ranged from 10 to 520 heads with an average of 106 animals, with goats and sheep being the dominant species. A majority of pastoralists perceived that the rainy season (monsoon) was starting later and ending earlier in the recent past, with an overall decrease in the number of days with rainfall. At the same time, most respondents acknowledged an increasing intensity of single rainfall events, along with more frequent flooding events. Regarding the cool winter season, most pastoralists perceived that the overall duration decreased with fewer rainy days, while the duration of the hot summer season was perceived to increase. Farmers' perceptions were partly contradicted by real time climate data, as average daily temperatures showed a slight decrease over the seven years of data collection. To adapt to climate change and extreme weather events, the respondents reported using strategies such as seasonal and annual migration with their herds and families, buying cereals (mainly maize and wheat) and fodder, working on lowland farms in exchange for crop residues, and using local shrub and tree shoots and leaves as alternative fodder during droughts.

Keywords: Climate change adaptation, extreme weather events, mountain pastoralism, vulnerability

Contact Address: Eva Schlecht, University of Kassel / University of Goettingen, Animal Husbandry in the Tropics and Subtropics, Steinstraße 19, 37213 Witzenhausen, Germany, e-mail: tropanimals@uni-kassel.de

Agro-pastoralists use participatory video making to reflect on their food environment in Turkana, Kenya

Irmgard Jordan¹, Angela Natukunda², Lydiah Maruti Waswa³, Céline Termote¹, Gudrun B. Keding⁴

¹The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

²Mt. Kenya University, Kenya

³Egerton University, Dept. of Human Nutrition, Kenya

⁴Justus Liebig University Giessen, Dept. of Nutritional Sciences, Germany

The food environment (FE) is the context in which people select, acquire, prepare, and consume food. It is a determinant of diet quality and nutritional outcomes.

This study invited young (agro-)pastoralists in two communities in the drylands in Turkana County, Kenya, to reflect on their FE to identify opportunities for improvement. Eight groups of 18–24-year-old adults (mean group size=5; mean BMI = 18.9 kg m^{-2}) were trained on the use of smart-phones to produce videos of their FE. Data from 7-day-dietary recalls, videos, concluding workshop and interviews with leaders were used for analysis.

Low literacy levels did not hinder group members to create videos. On average, participants had one meal per day. Fruits and vegetables (F&V) were mainly collected from the wild. Final videos showed the need of income opportunities to be able to purchase food, the importance and challenges of wild foods, vegetable gardening as options to easily access foods, food preparation methods, the quantity and diversity of foods usually consumed as well as eating practices. The participants expressed interest to improve their FE by scaling activities in local F&V production but are challenged by lack of water sources. Restoration of wild food trees to become more food secure in drought periods was mentioned especially in areas where water is sourced by digging holes in seasonal rivers. Community leaders observed increased engagement of participants with their FE during video making. Five months later, leaders reported that as a result of the project individual participants began trading goats for income or started vocational training.

Digital inclusion motivated the young adults to explore and reflect on options to improve their food environment. Income generation opportunities are needed for youths who did not have access to formal schooling. F&V farming is important to improve accessibility to perishable foods, while wild food restoration activities could serve as an alternative income opportunity to improve food and nutrition security. Participatory video making is feasible in areas with low literacy and contributes to eliciting young adult's views on their FE. This is a first step towards co-creation of meaningful bottom-up interventions.

Keywords: Agro-pastoralists, diet quality, drylands, food environment

Contact Address: Irmgard Jordan, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kaserani Rd, ICIPE Complex, 00621 Nairobi, Kenya, e-mail: i.jordan@cgiar.org

Social-ecological tipping points in the rangeland system in the Waterberg region in Namibia

Stefan Liehr¹, Markus Rauchecker¹, Marlen Britsch¹, Meed Mbidzo², Diego Menestrey Schwieger³

¹*ISOE – Institute for Social-Ecological Research, Germany*

²Namibia University of Science and Technology, Natural Resource Sciences, Namibia

³University of Cologne, Germany

The literature on ecological tipping points (TP) is well established and publications on social TPs are increasing, while empirical studies focussing on the interlinked socialecological perspectives of TPs are scarce. We studied social-ecological TPs in a rangeland system subjected to climate change to identify state changes with limited reversibility towards degradation in several cascades triggered by positive feedback loops running through the ecological and the social subsystem. For this, we analysed qualitative and quantitative data from extensive research on rangeland management in the Waterberg area in Namibia. One state change in the ecological subsystem is a cascading process going from a rangeland with abundant perennial and annual grasses to a rangeland dominated by annual grasses, to the occurrence of invasive species, and bare soil. Bush encroachment is the second detected ecological state change. The state change in the social subsystem is connected to the carrying capacity of the rangeland, farm income, and farm organisation. We identified several positive (self-reinforcing) feedback loops in the social-ecological system (e.g. drought - loss of grass biomass - reduction of carrying capacity - overstocking if there is no destocking because of drought – overgrazing – further loss of grass biomass – use of supplementary fodder to not destock – further overgrazing until the vegetation cover is depleted) resulting in system instability and driving the whole social-ecological system towards a TP. Furthermore, we identified farmers' coping strategies such as wildlife management and tourism as well as bush thinning and use, which lead to a negative feedback loop and enhance social-ecological system stability. Wildlife is better adapted to the ecosystems and bush thinning restores the rangeland temporarily. Both increase farm income and stabilise the social subsystem. In contrast, off-farm income stabilises the social subsystem, but leads to overstocking contributing to positive feedback loops in the social-ecological system. While the loss of vegetation cover and seedbank depletion are hardly reversible, bush encroachment can be reversed temporarily through bush thinning. There are signs of a negative social-ecological TP, but also of a state change to a more resilient social-ecological system.

Keywords: Livestock husbandry, rangeland degradation, wildlife management

Contact Address: Stefan Liehr, ISOE – Institute for Social-Ecological Research, Hamburger Allee 45, 60486 Frankfurt am main, Germany, e-mail: stefan.liehr@isoe.de

Land cover changes associated with the rise of the Lake Aydarkul in Nurota, Uzbekistan

Khaytbay Artikov, Martin Wiehle, Thanh Thi Nguyen, Andreas Buerkert

University of Kassel, Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics (OPATS), Germany

For many centuries Uzbekistan's arid to semiarid steppe biomes accommodate pastoral farming activities, while since the 1930s water- and input-intensive cropping systems have been introduced throughout the country's semi-arid lowland regions. Land use and land cover (LULC) change in these regions is accompanied by often negative effects on soil and pasture quality. In contrast to the well-documented and devastating consequences of desiccation and salinisation of the nearby Aral Sea region, a reverse scenario of LULC change has occurred in the central part of Uzbekistan. In 1969, heavy rainfall initiated large water inflow into the Chardara Reservoir, causing a release of enormous amounts of water, forming the Lake Aydarkul near the Nurota District. The subsequent changes of LULC, and their effects on local herders' livelihoods have been poorly investigated. This study aims at filling this gap by examining the processes of LULC changes triggered by cropping and livestock grazing using GISbased remote sensing. Time series analysis of historical Corona image from 1968 and Landsat (TM and OLI/TIRS) data covering 1987, 2000, 2010, and -2023 were employed using machine learning algorithm. The following LULC classes were distinguished: abandoned/bareland, built-ups, cultivated area, lowland pasture, highland pasture, trees/shrubs, and water bodies. First insights suggest that an increase in the lake level from 158 to 961 km² (1968 and 2023, resp.) has altered locations of livestock herding followed by a decrease of lowland areas. This has increased the pressure on existing lowland pastures. In addition, rainfed wheat (Triticum aestivum L.) cropping has extended by 182 % from about 5300 to 9600 ha (1968 and 2000), however, decreased to 33 ha (-99% cut off) in 2023 due to an unsustainable land management which resulted in tremendous land abandonment. Local land abandonment has increased by 145 % from 9989 ha in 1968 to 14050 ha in 2023, leaving soil bare, being invaded by unpalatable species, thereby decreasing the quality of the lowland pastures. Low quality pastures are likely unable to sustain the uncontrolled growing number of livestock and therefore herders forcibly continue to rely on the limited high-quality pastoral areas to keep their livestock.

Keywords: GIS, livestock, LULC, overgrazing, remote sensing, semiarid pastures, Uzbekistan

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

Stakeholder analysis and their roles in livestock disease reporting and response in pastoral areas in northern Kenya

Derrick Noah Sentamu¹, Raphael Lotira Arasio^{2,1}, Haron Akala³, Dennis N. Makau^{4,1}, Oliver Wasonga³, Joshua Orungo Onono¹

¹University of Nairobi, Dept. of Public Health, Pharmacology and Toxicology, Kenya ²Tufts University, Feinstein International Center, Friedman School of Nutrition Sci. and Policy, Uganda

³*University of Nairobi, Dept. of Land Resource Management and Technology, Kenya* ⁴*University of Minnesota, Dept. of Veterinary Population Medicine, United States*

Livestock plays an important role in the lives of pastoralists, whose entire livelihoods are structured around benefit from animals. One of the major constraints for pastoral production is livestock diseases, and the available disease surveillance systems are often difficult to implement under range conditions where pastoralists live. Furthermore, delays in disease outbreak reporting by pastoral communities to animal health workers is also a challenge that affects effective and timely response. This study aimed to investigate animal disease surveillance practices in pastoral areas of Northern Kenya. The study was carried out in Laisamis and Ngurunit Wards in Marsabit County. Data was collected on stakeholders within the pastoralists' production systems, their roles and animal health information flow between and amongst them; and methods used to transmit the information and their strengths and challenges. Findings revealed a network of 14 nodes (stakeholders) and 75 edges (links among the stakeholders), where the main stakeholders included: Animal Owners/Pastoralists (Degree = 22, Betweeness Centrality = 0.174, Page Rank = 0.173), Government Animal Health Workers (Degree = 22, Betweeness Centrality = 0.322, Page Rank = 0.145) and Non-Government Organisations (Degree = 10, Betweeness Centrality = 0.01, Page Rank = 0.087). There was an evolution from early methods used in disease outbreak reporting by communities from use of smoke, fire and walking on foot, to the presentday methods including riding on motor bikes, vehicles and use of mobile phones in passing the information on outbreaks. Furthermore, it describes evolution in livestock disease response pathways from solely relying on herbs to utilisation of animal health workers and modern synthetic drugs to respond to disease outbreaks in communities. The stakeholders involved in disease reporting and response have changed over time and new roles have been created with the expansion of the network. The major needs expressed by the pastoralists included: information on prevention, control and management of livestock diseases, bringing agrovets closer to communities and faster response to reports of disease outbreaks. In conclusion, an effective disease reporting and response system, requires utilisation of the roles and links among various stakeholders involved in this network.

Keywords: Disease, livestock, pastoralists, reporting, response

Contact Address: Derrick Noah Sentamu, University of Nairobi, Dept. of Public Health, Pharmacology and Toxicology, P.O. Box 29053, 00625 Kangemi, Kenya, e-mail: sentsderrick@gmail.com

Current state of enteric methane emissions and mitigation strategies from grazing systems in the tropics

Kwamboka Tirimba, Regina Birner, Mizeck Chagunda

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

Efficient livestock production systems that optimally supply livestock products with minimum enteric methane emissions (eCH_4) need to be adopted to lessen the contribution of this sector to climate change. However, cattle grazing in the tropics still report low productivity and high emission intensities compared to those in the temperate regions. This observation has been attributed to the low nutritive quality of tropical pastures and the high seasonal fluctuations of pasture availability. In this study, a meta-analysis of the tropical grazing systems was conducted to understand the trend of eCH₄ over a 15-year period (2008–2022) and the efficacy of eCH_4 mitigation strategies employed for cattle grazing systems in the tropics. A linear mixed model was employed to analyse data from 160 observations obtained from 29 studies, across 12 countries within the tropics. Fixed terms for the model included climatic zones, management systems, animal parameters and pasture diets. On average, eCH_4 were 130 g per day per cattle which formed the baseline of this study. We observed a decreasing trend in eCH_4 from 2012 to 2018 and a sharp rise between 2019 and 2020. There was a significant contribution of climatic zones to emissions (p < 0.001) with oceanic climates within tropics contributing highest emissions. Besides, the pasture diets significantly affected on emissions (p < 0.05) with mixed grass-legume pastures producing 17.6 % less emissions than the baseline. Intensively managed grazing systems had the highest dry matter intake and eCH₄ emissions. Adult female cattle had the highest eCH_4 (223.18g per day per cattle) across the animal types. On mitigation strategies, we found that eCH₄ reduced over the years with the adoption of improved pasture diets and management methods. This indicate that improving feeding and management strategies was effective in methane mitigation. The variation of emissions across the management systems and pasture diets were highly dependent on the average temperature and precipitation of a region. As the type of climate had a high influence on eCH_4 , it was concluded that feeding and management strategies would be more effective when adopted based on the specific climatic parameters of a region.

Keywords: Adaptation, cattle productivity, greenhouse gas emissions

Contact Address: Kwamboka Tirimba, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr. 17, 70599 Stuttgart, Germany, e-mail: kwamboka.tirimba@uni-hohenheim.de

Holistic approach of soil health in a rangeland in northern Mexico: Development of an index

Pamela Fernanda Mejía Leyva, Alfredo Pinedo Álvarez, Federico Villarreal Guerrero, Carlos Morales Nieto, Jesus Alejandro Prieto Amparan

Autonomous University of Chihuahua, Natural Resources, Mexico

Soils are affected by a complex interplay of multiple physical, chemical and biological processes that form its' functionality and resilience to degradation. Soil health indexes have been mostly developed for agricultural lands but they are rarely adopted to rangeland ecosystems. However, rangelands provide important agroecological services including native vegetation as feed source to grazing animals. At the same time, increasing pressure, due to overstocking and the introduction of more aggressively browsing livestock species, threaten the vulnerable ecosystems. In northern Mexico, sustainable rangeland management approaches are being developed testing the impacts of native Criollo cattle in comparison to the meanwhile widely introduced Angus and mixed Angus breeds on vegetation and soil health. Criollo cattle have shown to exert less pressure on the ecosystem and to thrive in harsh conditions, but science-based evidence on soil health states and trends is rare.

The aim of the study is to develop an index to assess soil functionality of semi-dry rangelands in northern Mexico. Specifically, to a) define robust indicators, and b) to develop an index to compare the impact of three cattle breeds namely Criollo, Angus-Hereford and Criollo-Angus. An experiment is being conducted at the "Teseachic" ranch in Chihuahua, Mexico where 2,000 ha were divided into six paddocks with areas between 225 and 400 ha. The paddocks have three control areas of approximately 60 m² each, distributed at the bottom, medium and upper terrain. The following soil indicators were obtained: soil aggregate stability, porosity, infiltration, visual evaluation of soil structure, organic carbon, electric conductivity, total nitrogen, active carbon, and pH. Three soil categories corresponding to specific roles the soil performs i.e., soil functions will be evaluated. These are: i) hydrological, focused on the ability of the soil to control erosion and floods; ii) productive regarding food and fibre production; and iii) ecological meaning the capacity of the soil for nutrient cycling and carbon sequestration. This study will allow a holistic assessment of soil health. Additionally, it will provide information about different cattle breed impacts on soil functionalities to promote the adaptation of versatile breeds in a changing climate.

Keywords: Criollo cattle, rangelands, soil functions, soil health, soil indicators

Contact Address: Alfredo Pinedo Álvarez, Autonomous University of Chihuahua, Natural Resources, Perif. Francisco. R. Almada km 1 Pavis Borunda, 31453 Chihuahua, Mexico, e-mail: apinedo@uach.mx

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Evaluating the influence of *Lagenaria breviflora* fruit extract on growth performance, hematological parameters, and serum biochemistry in broiler chickens

Oluwagbemiga Adeleye¹, Amos Kolawole², Oluwatosin Dosumu³, Ibiyemi Opowoye^{4,1}, Lawrence Egbeyale¹

¹*Federal University of Agriculture, Abeokuta, Dept. of Animal Production and Health, Nigeria*

²Federal University of Agriculture, Abeokuta, Dept. of Microbiology, Nigeria

³Federal University of Agriculture, Abeokuta, Dept. of Biochemistry, Nigeria

⁴Inst. of Food Security Environmental Resources and Agricultural Research (FUNAAB), Nigeria

The utilisation of natural supplements in poultry production has gained considerable attention as alternatives to conventional growth promoters and health enhancers. This study investigated the impact of Lagenaria breviflora fruit extract (LBFE) on various parameters of broiler chicken performance and health. 240 day old broilers chicks (Ross 380 strain) were replicated four times with twenty (20) birds per replicate. Layout was Completely Randomised Design and birds in treatment group 1 - control group were administered conventional coccidiostat and antibiotics (5% oxytetracycline hydrochloride at a dosage of 5 g per 4 litres of drinking water). The treatment was labeled- $0 g l^{-1}$ LBFE. Birds on treatment group 2 were given dose $300 g l^{-1}$ LBFE thrice a week and birds on treatment group 3 were given dose 500 g l⁻¹ LBFE thrice a week throughout the experimental period (6 weeks). Growth performance parameters, carcass characteristics, hematological indices, and serum biochemical profiles were assessed. Results revealed that the performance and carcass evaluation of broiler chickens at both starter phase (week 1–4) and finisher phase (week 5–6) were not significantly (p > 0.05) influenced by LBFE at varying doses. Moreover, haematological parameters indicated that the RBC and WBC values were increased significantly (p < 0.05) while MCH value was decreased significantly (p < 0.05) for birds on 500 gl⁻¹ LBFE compared to values for birds on 0 gl⁻¹ LBFE suggesting potential immunomodulatory effects of the fruit extract. Additionally, serum biochemical analysis revealed a significant (p < 0.05) increase for glucose (155.04 mg dl⁻¹), total protein $(57.7 \text{ g} l^{-1})$, albumin $(42.75 \text{ g} l^{-1})$, uric acid $(61.19 \text{ g} l^{-1})$, creatinine $(0.66 \text{ mg d} l^{-1})$, total bilirubin 0.82 mg dl⁻¹), and AST (49.61 μ l⁻¹) values in control treatment compared to values from other treatments which were significantly (p > 0.05) reduced indicative of improved physiological health in supplemented birds. These findings suggest the beneficial effects of LBFE on broiler chicken performance, carcass characteristics, hematological indices, and serum biochemistry, thus highlighting its potential as a natural supplement for optimising poultry production and health.

Keywords: Broiler, growth performance, haematological indices, serum biochemistry

Contact Address: Oluwagbemiga Adeleye, Federal University of Agriculture, Abeokuta, Dept. of Animal Production and Health, Alabata, 110001 Abeokuta, Nigeria, e-mail: adeleyeoo@funaab.edu.ng

Effects of disease control strategies on the efficiency of chicken production in Ghana's Bono region

Desmond Ayertey¹, Freda Asem¹, Charles Okyere¹, Dolapo Enahoro²

¹University of Ghana - Legon, Department of Agricultural Economics and Agribusiness, Ghana

²International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Ghana

Viral diseases among layer chickens threaten the incomes of small to medium-sized commercial chicken farms in Ghana. Implementing adequate biosecurity measures aids in controlling the spread of these diseases and can improve production efficiency, thus increasing farmer incomes. However, limited knowledge of biosecurity practices, high cost of chemicals, irregular veterinary visits, and negligence on the part of farmers, limit the practice of good biosecurity on farms. This study assessed the technical efficiency of the intensive housing system of layer production and the factors that influence it among small and medium-sized chicken farms in Ghana's Bono region. A normalised Cobb-Douglas production frontier model was employed using crosssectional data of 140 layer chicken producers in two districts (Dormaa Central and Dormaa East) of the Bono Region. Inputs variables of the empirical model included feed consumption, water consumption, vaccination and other medications, and labour (man-days), while the (number of crates of) eggs produced was defined as the output. These factors were standardised per 1,000 birds. The study found that the quantity of feed and water consumption are the most significant factors negatively and positively, respectively, affecting egg production levels. Layer producers are found to be about 73 % production efficient. Farmer's age and one biosecurity control strategy (depopulation of birds during extreme hot weather conditions or disease outbreak) are the key factors that significantly explain variations in production efficiency. Other biosecurity factors that were mentioned and mostly practised were the use of footbath, frequent disposal of litter, routine deworming, frequent in-house cleaning, and regular veterinary visits. The results suggest that more regular visits to farms from the public veterinary service, the primary means by which the surveyed farms receive reliable information on the strategies and importance of implementing biosecurity measures, may be key to increasing efficiency levels among the farmers. Farmer education on early detection and control of viral poultry diseases, and improved access to properly formulated feeds, were also found to be important.

Keywords: Livelihoods, livestock, Marek disease, poultry, smallholder, technical efficiency

Contact Address: Dolapo Enahoro, International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Accra, Ghana, e-mail: d.enahoro@cgiar.org

Awareness and mitigation measures of aflatoxin among poultry farmers and feed millers in Ijebu-Ode and Igbesa areas of Ogun state, Nigeria

Oluwole Sikiru Banjo, Adekoyejo Oyegunwa

Tai Solarin University of Education, Dept. of Animal Science, Nigeria

Aflatoxin, a very important mycotoxin produced by Aspergillus flavus and Aspergillus parasiticus has become a nightmare to farmers and feed millers in Nigeria. In a preliminary study conducted in Ijebu-Ode, Ogun State, Nigeria, it was discovered that many of the feed ingredients used in producing feed for farmers have high contents of aflatoxin, hence the current study. Poultry feed ingredients which comprises of maize, peanut meal, soya bean meal and mixtures of maize, groundnut cake and other crops have been associated with mycotoxin contamination during crop production and storage, with limited attention given to this by local poultry farmers and regulatory bodies. Food and Agriculture Organisation report states that about up to a quarter of the world's growing crops are affected by mycotoxins each year. In this study, level of awareness and mitigation measures of aflatoxin among poultry farmers and feed millers in Ijebu-Ode and Igbesa area of Ogun State, Nigeria was assessed. Using a descriptive survey design, 120 respondents, comprising poultry farmers and feed processors were sampled. The structured questionnaire measured among other things the demographic information of the sampled population, their level of awareness of aflatoxin and mitigation practices. The results revealed that majority (88.34%) of respondents were aged 18–50 years. The industry appeared male-dominated, with 70.9%. Out of the sampled population, 59.17% were married, and educational attainment reveals that 58.82 % had tertiary education. Regarding mycotoxin awareness, 52.72 % of respondents were unaware, and farmers and processors exhibited similar knowledge about influencing factors and dangers. The findings underscored the urgency of tailored interventions and educational programmes to enhance awareness and practices among poultry stakeholders in the region.

Keywords: Aflatoxin, awareness, farmers, mitigation

Contact Address: Oluwole Sikiru Banjo, Tai Solarin University of Education, Dept. of Animal Science, Ijagun, Nigeria, e-mail: banjoos@tasued.edu.ng

Assessment of cassava as a partial substitute for maize in local chicken diets: Performance and economic evaluation

Ebenezer Mba¹, Chinedu Okwum¹, Ikechukwu Albert²

¹Michael Okpara University of Agriculture, Umudike, Animal Production and Livestock Management, Nigeria

²Michael Okpara University of Agriculture, Umudike, Animal Nutrition and Forage Sci., Nigeria

The growing demand for maize for industrial and domestic uses in Nigeria has led to increased costs of poultry products. This poses a risk of resource-constrained households failing to meet the daily protein requirements, especially for children, in the absence of an effective maize replacement in poultry diets. This study aimed to evaluate the feasibility of substituting maize with cassava in local chicken diets and its impact on performance and economic viability. The research was conducted at the livestock research station of Michael Okpara University of Agriculture Umudike (MOUAU) in 2023. A total of 160 local chickens were randomly assigned to four treatments in a completely randomised design, with each treatment group containing four levels of cassava inclusion at 0%, 25%, 50%, and 75% in the diets compared to maize-based commercial feed as a control. Each treatment was replicated four times, with ten birds per replicate. Over 180 days, the chickens were assessed for performance parameters including growth rate, feed intake, and feed conversion ratio. Additionally, an economic analysis was conducted to evaluate the cost-effectiveness of cassava inclusion in the diets. Results indicated that birds fed diets with a medium dose (50%) of cassava had the highest feed intake at 1 to 24 and 1 to 35 days of age among the cassava-based diets. However, a significant decrease in body weight was observed at 75 % cassava inclusion, and the feed conversion ratio was highest at 50% cassava inclusion. Our data show that chickens fed diets with 50 % cassava inclusion exhibited similar growth rates, feed intake, and feed conversion ratios compared to those fed maize-based diets. Furthermore, economic analysis showed that substituting maize with cassava at this level could yield potential cost savings without compromising performance. This study demonstrates the feasibility of incorporating cassava as a partial replacement for maize in local chicken diets, particularly at the 50% inclusion level. The findings indicate that such dietary modifications can not only maintain performance but also offer economic benefits to poultry producers. Further research is recommended to explore optimal inclusion levels and the long-term effects on chicken health and production.

Keywords: Cassava, economic analysis, livestock diet, local chickens, maize, performance

Contact Address: Ebenezer Mba, Michael Okpara University of Agriculture, Umudike, Animal Production and Livestock Management, No. 2 Chukwu Avenue Government College, 440101 Umuahia, Nigeria, e-mail: ebenezerchimdi@gmail.com

The effect of algal biomass supplementation on performance and welfare of rabbit does and kits

Oluwagbemiga Adeleye¹, Iyanuoluwa Fajenyo¹, Ibiyemi Opowoye^{2,1}, Lawrence Egbeyale¹

¹*Federal University of Agriculture, Abeokuta, Dept. of Animal Production and Health, Nigeria*

²Inst. of Food Security Environmental Resources and Agricultural Research (FUNAAB), Nigeria

One of the challenges confronting rabbit production is mortality of rabbit kits most especially at birth. This research aimed to investigate the effects of algal biomass supplementation on the performance and welfare of rabbit does and kit survival. Twenty does (mixed breed) with an average weight of 1.8 kg was used for this study. Four bucks (mixed breed) was used for mating (1buck: 5 does). The does were randomly divided into four treatments and five replicates: treatment one: 0% algal biomass, treatment two: 0.5% algal biomass, treatment three: 1% algal biomass, treatment four: 1.5%algal biomass was included in the diets. Forage (*Tridax* spp) and finished concentrate feed purchased from a known feed company was fed to the rabbits. Hand-mating method was used and pregnancy test was carried out 14 days after mating. The experiment lasted for eight weeks from gestation to four weeks after parturition. Growth, reproductive, welfare and behavioural parameters including vital signs were monitored. In addition, hematological parameters, serum biochemical profiles, and indicators of oxidative stress were assessed. Data collected was analysed using One way analysis of variance. Tukey test was used to separate the means. Results revealed that rabbit does supplemented with 1.5% algal biomass exhibited significantly higher body weight gain, higher litter size, vital kits and improved feed efficiency (p < 0.05). Furthermore, serum biochemical profiles indicated enhanced metabolic functions. Rabbit does in the algal biomass supplemented group displayed reduced signs of stress, and enhanced reproductive performance compared to the control group. These findings suggest that algal biomass supplementation positively impacts both performance and welfare of rabbit does and kits.

Keywords: Algal biomass, rabbits, animal welfare

Contact Address: Oluwagbemiga Adeleye, Federal University of Agriculture, Abeokuta, Dept. of Animal Production and Health, Alabata, 110001 Abeokuta, Nigeria, e-mail: adeleyeoo@funaab.edu.ng

Effect of different levels of *Tenebrio molitor* larva meal inclusion on chicken meat quality

Daniela Huamaní Cárdenas 1 , Khaterine Salazar-Cubillas 2 , Giovanna Gómez-Oquendo 3,1

¹Universidad Cientifica del Sur, Fac. of Veterinary and Biological Sciences, Peru

²*Christian Albrechts University of Kiel, Institute of Animal Nutrition and Feed Science, Germany*

³La Molina National Agrarian University, Fac. of Veterinary and Biological Sciences, Peru

The poultry industry will increase its production thanks to population growth. Due to this, there will be an increase in demand for supplies used in poultry diets, highlighting protein supplies such as fish meal and soybean meal (SM). The obtaining of these ingredients is affected by various problems, making it necessary to evaluate other elements to guarantee the protein nutrition of poultry. One of the alternatives to this problem is *Tenebrio molitor* larva meal (TMM). Therefore, the objective of the study was to evaluate the meat quality of chicken fed with a conventional diet that contained SM as the main protein source, and meat from chickens fed with inclusions of 5%, 10% and 15% of TMM in replacement of SM; through the evaluation of its sensory, physicochemical and nutritional characteristics. For the analyses, 8 broilers were randomly selected from each treatment (4): T0, 100 % soybean cake as the main protein ingredient (conventional diet); T1, inclusion of 5% TMM; T2, inclusion of 10% TMM and T3, inclusion of 15% TMM. The inclusion of TMM in the diets did not influence the sensory characteristics of appearance and odor (p > 0.05); on the contrary, in the juiciness (p = 0.00), flavor (p = 0.03), softness (p = 0.00) and texture (p = 0.01) significant differences were obtained (p < 0.05) between treatments T0 and T1 with respect to to T2 being similar to T3. In the case of physicochemical characteristics, in acidity, water activity, thawing and cooking loss, no significant differences (p > 0.05) were observed between treatments. The use of TMM in the diet of broiler chickens is possible, despite this, it is essential to focus on consumer opinion by including a higher percentage of inclusion of TMM, requiring more studies to determine its reliability as an ingredient in the feeding of chickens raised for human consumption.

Keywords: Breast muscle, broilers, insect, meat quality, Tenebrio molitor

Contact Address: Giovanna Gómez-Oquendo, La Molina National Agrarian University, Fac. of Veterinary and Biological Sciences, Jiron Simón Bolivar 643, 15419 Lima, Peru, e-mail: ggomez@cientifica.edu.pe

Substitution of soyabean meal with *Moringa stenopetala* leaf meal positively influenced feed consumption and egg production: A novel approach to enhance poultry products in the rural communities

KIBRU BERISO¹, VERA SOMMERFELD², MARKUS RODEHUTSCORD²,

Aberra Melesse¹

¹*Hawassa University, School of Animal and Range Sciences, Ethiopia* ²*University of Hohenheim, Dept. of Animal Nutrition, Germany*

Moringa stenopetala is endemic to Ethiopia where it is widely distributed in southern parts of the country. One of the limiting factor of poultry nutrition in the tropics is the availability and accessibility of protein supplements such as soybean meal which is considered as the main protein source in poultry nutrition. The objective of this study was thus to evaluate the efficiency of substituting soyabean meal (SBM) with graded levels of Moringa stenopetala leaf meal (MSL) on feed consumption and egg production performances of Lohmann-tradition chicken breeds. A diet was formulated to contain MSL at a rate of 0 (MSL0), 3 (MSL3), 8 (MSL8) and 13 % (MSL13) by replacing the soybean meal of the control diet. Diets were formulated to be isocaloric and isonitrogenous with similar energy density and protein level. Forty pre-laying pullets of Lohmann-tradition chicken breed were randomly distributed to each treatment diet replicated four times with ten hens per replicate. Data were collected on egg number, egg weight and feed intake between 20 and 28 weeks of hen's age on daily basis. The rate of hen housed egg production (HhEp), egg mass (EM) and feed conversion ratio (FCR) were computed. The substitution of SBM with MSL did not affect HhEp, egg weight, EM and FCR. The average daily feed intake per hen reared in MSL0, MSL3, MSL8 and MSL13 diets was 112, 109, 119 and 125 g, respectively, being higher (p < 0.05) for hens fed with the MSL13 diet than those of MSL0 and MSL3 diets. The respective individual HhEP for hens fed on MSL0, MSL3, MSL8 and MSL13 diets was 61.0, 58.5, 63.3 and 58.3 %. The mean egg weight of hens reared in MSL0, MSL3, MSL8 and MSL13 diets was 53.5, 53.3, 54.1 and 53.5 g, respectively. Hens fed with MSL0, MSL3, MSL8 and MSL13 diets produced 1.60, 1.53, 1.68 and 1.54 kg EM per hen, respectively. The FCR of hens fed on MSL0, MSL3, MSL8 and MSL13 diets was 3.39, 3.46, 3.40 and 3.94 kg feed/kg EM, respectively. It can be concluded that the MSL was more palatable and could effectively substitute upto 15% of the costly SBM as protein source in the layer hens' diet under tropical production environments.

Keywords: Egg production, feed consumption, Lohmann-tradition chickens, *Moringa stenopetala*, soybean meal

Contact Address: Aberra Melesse, Hawassa University, School of Animal and Range Sciences, Hawassa, Ethiopia, e-mail: a_melesse@uni-hohenheim.de

Growth performance and economic analysis of broiler chickens fed turmeric rhizome powder (*Curcuma longa*)

Glory Eddy Enyenihi¹, Emmanuel Nnaji Ogbuzuru¹, Ubak E Ekpo²

¹University of Uyo, Animal Science, Nigeria ²Vika Farms Ltd, Training Educational Department, Nigeria

This study was conducted at the University of Uvo Teaching and Research Farm to evaluate the impact of turmeric rhizome powder (TRP) as a growth promoter on growth performance of broiler chickens and cost efficiency of broiler production. A total of 120 Ross 308 strains of broiler chickens were divided into four treatment groups, which were further replicated three times with 10 birds each per replicate in a Completely Randomised Experimental Design. The experimental groups were made up of the birds on the control diet (T1), and three experimental groups that were fed diets with TRP supplementation at 200 g (T2), 400 g (T3), and 600 g (T4) per 100 kg of feed. The experiment lasted 8 weeks, during which data on weight gain, feed efficiency and cost efficiency were collected. Analysis of Variance (ANOVA) was adopted to detect significant differences between the treatment means while post hoc analysis using Duncan Multiple Range Test further differentiated the means. The results revealed that the birds on T3 diets (400 g TRP) exhibited the highest weight gain (1508.33g), demonstrating the potential of TRP supplementation at that level of supplementatoion to enhance broiler growth performance. Furthermore, the cost analysis reveals that the cost per kilogram weight gain was least in the treatment fed 400 g of TRP (N959.00). Equally, the revenue and the gross margin was also highest in the treatment fed 400 g of TRP (N1885.00, N439.00). In contrast, exceeding this level of 400 g supplementation, as observed in the T4 group (600 g TRP), led to an increase in production costs without any proportional improvement in weight gain.

Keywords: Additve, broiler, cost, growth promoter, profitability, turmeric

Contact Address: Glory Eddy Enyenihi, University of Uyo, Animal Science, Ikpa Road, Uyo, Nigeria, e-mail: gloryenyenihi@yahoo.com
Ex-ante impact of Marek's disease mitigation on economic viability of small-scale intensive layer production in Ghana

Joshua Aboah¹, Dolapo Enahoro²

¹CSIRO, Food Systems Dynamics Unit, Australia

²International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Ghana

The mitigation strategies for control of Marek's disease in poultry production include revaccination (double vaccination) of day-old chicks, selection of genetically resistant breeds, and the implementation of biosecurity measures. However, limited evidence exists regarding the economic impact and trade-offs of adopting these mitigation strategies either alone or in combination with others. This study examines the exante impact and trade-offs associated with the implementation of strategies against Marek's disease on the economic viability of small-scale intensive layer production systems in Ghana. The analyses focused on four producer typologies – including locally hatched chicken cohort and systematic production schemes as well as imported cohort and systematic production schemes.

A system dynamics model, segmented into three modules comprising of an integrated production-epidemiological, financial, and management decision modules, was developed using the Stella Architect software, parameterised with a mix of primary and secondary data, and simulated for 700 days at a daily timestep. The model structure was validated with stakeholders using a participatory approach, while extreme condition tests were conducted to validate the robustness of the model behaviour.

The findings reveal that implementing revaccination can mitigate the economic impact of Marek's disease for farmers using locally hatched day-old chicks, reducing losses by 76.27 % and 76.31 % in systematic and cohort production schemes, respectively. However, revaccination alone fails to alleviate the economic impact when using imported day-old chicks. Under both cohort and systematic schemes, Marek's disease-related losses rise by an average of 25.58 %.

Comparatively, implementing only biosecurity measures is more cost-effective than relying solely on revaccination. The average benefit cost ratio for revaccination increased from 0.39 to 1.18 and 0.40 to 1.22 when exposed and infected birds are culled by farmers in cohort and systematic production schemes, respectively. Opting for systematic production with locally hatched day-old chicks over cohort production with imported day-old chicks results in a gross margin loss of 0.87 % \pm 8.31 with biosecurity measures alone and 0.21 % \pm 3.11 with revaccination alone. This study's findings inform poultry farmers about some cost-effective disease mitigation strategies available to them in the control of Marek's disease.

Keywords: Biosecurity, chicken, food security, systems dynamics, vaccination

Contact Address: Joshua Aboah, CSIRO, Food Systems Dynamics Unit, 306 carmody road, 4067 St lucia, Australia, e-mail: joshua.aboah@csiro.au

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Sustainable diets and nutrition for different target groups

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Mothers' routine and problem-solving actions in promoting child health and nutrition in Kenyan drylands

Patricia Kiprono¹, Brigitte Kaufmann²

¹*German Institute for Tropical and Subtropical Agriculture (DITSL), Kenya* ²*German Institute for Tropical and Subtropical Agriculture (DITSL), Germany*

In the drylands of northern Kenya, mothers strive to promote the health and nutritional well-being of their children, but face many challenges. Most studies, especially those focusing on (agro)-pastoralists use a problem-lens, with recommended standard interventions to improve child nutrition that do not necessarily fit to the local conditions. This study aims to explore (agro)pastoral women's knowledge and their practical solutions in child nutrition and care, uncovering their routine and problem-solving actions.

The Activity Knowledge Analysis tool was used in 16 Focus Group Discussion sessions with women-caregivers of children below the age of five years from Marsabit County, Kenya. The discussions were recorded, transcribed and thematically analysed using MAXQDA software.

Mothers perform routine actions encompassing age-appropriate feeding practices, maintaining hygiene, and facilitating the child's developmental milestones to achieve their goal of having a healthy child. Some of the routine actions include providing special diets, responsive feeding; personal, food and environmental hygiene; massage, engagement in play and interaction to facilitate development. The challenges that mothers face include maintaining their own health, difficulties with feeding, and delayed developmental milestones. These challenges are further compounded by contextual factors; poverty, time constraints and lack of support. To overcome the challenges, mothers used a range of problem-solving actions, including enriching their children's diets, diversifying their income sources, borrowing food or money, and seeking for social support from family members and the community.

This study demonstrates the complex interplay of various factors, including cultural, social, economic, and environmental, that influence maternal practices and child health outcomes. This highlights the need for a multifaceted approach that takes into account socio-economic factors and provides support systems to empower mothers to effectively promote the well-being of their children.

Keywords: Arid areas, caregivers, challenges, child development, knowledge, pastoral, practices, solutions, strategies

Contact Address: Patricia Kiprono, German Institute for Tropical and Subtropical Agriculture (DITSL), Steinstr. 19, 37213 Witzenhausen, Kenya, e-mail: patriciakiprono@gmail.com

Agroecology on the school food menu, the seeds of a sustainable transition

MODOU GUEYE FALL¹, ASTOU DIAO CAMARA¹, JEAN DANIEL CESARO² ¹Institut Senegalais de Recherches Agricoles (ISRA), Bureau of Macro-Economic Analysis (BAME), Senegal

²Center for International Coop. in Agricultural Research for Development (CIRAD), Mediterranean and Tropical Farming Systems (SELMET), France

In Senegal, food insecurity among children is a real obstacle to school attendance. To counter this, school policies in the most vulnerable areas, such as the Fatick Region, have integrated school canteens to support children's schooling and education. Implemented in at least 11% of Senegal's elementary schools, these canteens provide pupils with two meals a day. In the Fatick region, the canteens are supplied with local products such as millet, the main staple cereal, and milk. In this way, they provide a real lever for promoting local products and shortening supply chains, in favour of a circular economy. In addition to shortening commercial circuits with school canteens, Fatick's farmers and agropastoralists are already in the agro-ecological transition. In fact, they have co-created a local dynamic for agro-ecological transition (DyTAEL), affiliated to a national multi-actor movement. The DyTAEL, made up of several players including farmers, civil society, politicians and national and international research, has drawn up a vision for an agroecological Fatick by 2035. This ambition has been translated into a multi-year action plan. With a view to operationalizing the action plan, the Senegal agroecological initiative (AEI) team has chosen DyTAEL as its Agroecological Living Landscape (ALL) to support, among other things, the implementation and co-development of profitable agroecological business models that are sensitive to the principles of the circular economy and the development of local food systems. To this end, the B-act_Tool is used to assess business models that are supported by a participatory guarantee system (GSP) for compliance with agroecology. In this respect, value chain mapping and analysis has identified and consolidated strong links between school canteens and millet and milk producers. The links are synergistic and mutually beneficial, with positive externalities for the region. For the canteens, supply is stabilised with healthy products. As for producers, they have a secure market, encouraging their efforts to make the transition to agro-ecology. In its ambition to develop an agroecological territory, DyTAEL has the opportunity to introduce agroecology into schools, and to see children already aware of the principles and benefits of agroecology at elementary level.

Keywords: sustainable, agroecology, DyTAEL, school canteens, school food, transition

Contact Address: Modou Gueye Fall, Institut Senegalais de Recherches Agricoles (ISRA), Bureau of Macro-Economic Analysis (BAME), Cité Fadia, Dakar, Senegal, e-mail: modougf@yahoo.fr

Ensuring food and nutrition security in Africa through the diversification of the food systems

Emmanuel Donkor¹, Michael Frei¹, Erasmus Tang², Dominique Van Der Straeten³, Christophe Matthys⁴, Alisdair Fernie⁵, Tiziana de-Magistris⁶, Odia B. Cisse⁷, Amaka Chime⁸, P. C. Sibiry Traoré⁹, Rousseau Djouaka¹⁰, Sharon Chacha¹¹, Mube K. Hervé¹², Paul Z. Diby¹³, Ina Danquah¹⁴, Derick Metiofe¹⁵, Irmgard Jordan¹⁶, Kassi Elia¹⁷, Benedikte Grenov¹⁸, Juliana Kiio¹⁹, Haris I. Parvez²⁰, Tsanko Gechev²¹

- ¹Justus Liebig University Giessen, Inst. of Agronomy and Plant Breeding, Germany
- ²*Africa Rice Center (AfricaRice), M'be Research Station, Côte d'Ivoire*
- ³*Ghent University, Laboratory of Functional Plant Biology, Dept. of Biology, Belgium*
- ⁴University Hospitals Leuven, Dept. of Chronic Diseases and Metabolism & Dept. of Endocrinology, Belgium

⁵Max-Planck-Institute of Molecular Plant Physiology, Germany

⁶Agrifood Research and Technology Centre of Aragón (CITA), Spain

- ⁷ Regional Centre of Excellence against Hunger and Malnutrition, World Food Programme, Côte d'Ivoire
- ⁸Africa Projects Development Centre, Nigeria

⁹Manobi Africa, Mauritius

- ¹⁰International Institute of Tropical Agriculture, Benin
- ¹¹Food Security for Peace and Nutrition-Africa, Kenya

¹²University of Dschang, Faculty of Agriculture and Agricultural Sciences, Cameroon

- ¹³Entreprise en Sante et Securite au Travail, Côte d'Ivoire
- ¹⁴Bonn University, Germany
- ¹⁵Agribusiness Vocational Training Centre, Cameroon
- ¹⁶The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya
- ¹⁷Opportunities Industrialisations Center International Côte d'Ivoire, Côte d'Ivoire
- ¹⁸University of Copenhagen, Dept. of Nutrition, Exercise, and Sports, Denmark

¹⁹Kenyatta University, Dept. of Food, Nutrition and Dietetics, Kenya

²⁰De Montfort University, Leicester School of Allied Health Sciences, Fac. of Health and Life Sciences, United Kingdom

²¹Center of Plant Systems Biology, Bulgaria

The triple burden of malnutrition, undernutrition (stunting, wasting, underweight), overnutrition (overweight, obesity), and micronutrient deficiencies, remains prevalent in Africa. This problem hinders economic development and growth, while overburdening Africa's fragile health systems. Global nutrition is dominated by 15 highly developed crop species providing about 70 % of human calories, although 50,000 plant species are edible. Meanwhile,

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

crop diversity is declining at the allelic, genotypic and species levels. This one-sided food production is vulnerable to diseases and pests and climate change and variability. Against this background, HealthyDiets4Africa, a sixyear (2023-2028) EU-funded project, aims to harness the potential of food system diversification to combat malnutrition, enhance food and nutrition security in Ivory Coast, Benin, Ghana, Liberia, Nigeria, Cameroon, Uganda, and Kenya. The project objectives include 1) establishing dietary diversitymonitoring framework for food systems using new established metrics, 2) developing technologies for sustainable diversification of food production, including new varieties of major crops, innovative production systems for underutilised crops, and diversification of existing cropping systems, 3) enhancing consumer acceptance and adoption of diversified sustainable food products that support human health, and 4) promoting wide acceptance and adoption of diversified food systems. Since the start of the project in 2023, the following results have been achieved: 1) a multi-level mixed-methods approach has been used to develop solutions and evidence-based decision matrix aiming at the reducing risk of malnutrition and food environment information has been compiled, indicating entry points for interventions, 2) seven living labs have been established in six African countries to identify, develop and pre-test innovations for upscaling to promote diversified sustainable food systems, 3) about 24 underutilised plant species with limited nutritional information have been selected for nutritional analysis, which will be incorporated into a comprehensive nutritional composition database developed by the project using existing databases and literature, 4) over 50 nutritious crop species, including vegetables, cereal/grains, roots/tubers, legumes, and nonforest timber products are targeted in the project, and 5) sustainable innovations and practices are being identified and developed for upscaling, 6) youth and women are being trained in sustainable food production systems and best agribusiness management practices to reduce youth unemployment.

Keywords: Diversification, food and nutrition security, food systems, food value chains, innovations, interdisciplinary and translation approach, sub-Saharan Africa, sustainable diets

Exploring the maternal factors affecting children's nutritional status in urban areas of Bangladesh

MD. NAZMUL HOQUE, SADIKA HAQUE Bangladesh Agricultural University, Agricultural Economics, Bangladesh

With the growing urbanisation in Bangladesh, socio-demographic structure is changing similar as many other countries in the world, where women are increasingly joining to the labour force. Evidence shows that urban women have more opportunity to be employed, who have more access to economic resources, which may exert influences in household food consumption behaviour and care practices. At the same time, women in Bangladesh are also traditionally responsible for childcare and all other reproductive works at the household. Therefore, the study was conducted to identify the maternal factors which affect children's nutritional status in urban areas in Bangladesh. To accomplish the study, primary data was collected from 1978 mothers about mother herself and her youngest child aged between 6 to 59 months. The child nutrition outcomes were calculated based on anthropometric z-scores for children under five, calculated using the 2006 WHO Child Growth Standards. The study found that 36% of urban children are stunted, 16% are underweight, 10% are wasted, while 33% of them are at risk of being overweight. From multinomial logistic regressions, the study found that mothers' socio-economic status, educational qualification, nutritional knowledge, BMI, receiving antenatal care (ANC), status of empowerment, childcare support, and sanitation status - were the important factors influencing child nutritional status. Working mothers provided less breast feeding, and faced problems with complementary feeding, as they had to join at work after maternity leave. Most working mothers depended on female relatives to attend to their children or gave the responsibility to unprofessional domestic workers. The problems of urban working women that are emerging include triple burden of responsibilities living in a nuclear structure of family which need utmost importance to be given. In the structural rearrangement of urban and peri-urban settings, children's physical and mental growth and development has become a critical concern, which is an overlooked component in Bangladesh. With this background, this study recommends introducing day care centers with trained staff, quality antenatal care services, inclusion of low-income mothers in the social safety net programme for the mothers living in urban and peri-urban Bangladesh.

Keywords: Antenatal care, maternal factors, stunted, urbanisation

Contact Address: Md. Nazmul Hoque, Bangladesh Agricultural University, Students' Affairs Division, Mymensingh, Bangladesh, e-mail: nazmulhoque.dsa@bau.edu.bd

Improving children's nutrition: Evidence-based policy recommendations for school meal programmes in urban Vietnam

Thi Kim Anh Dinh¹, Quoc Toan Luu¹, Simone Kathrin Kriesemer³, Cory Whitney², Thi Thu Giang Luu³

¹*Hanoi University of Public Health, Fac. of Environmental and Occupational Health, Vietnam*

²University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany

School meals can be an essential part of child health and nutrition; they are central to school-aged children's food environments and often fulfil a substantial portion of a child's daily nutritional requirements. In Vietnam, ensuring nutritional school meals has been prioritised through resolutions, projects, national strategies, guidelines, circulars, and documents concerning school meals, all aimed at promoting good nutrition and preventing diet-related disorders in children. Challenges to implementing such policies persist, particularly in urban areas. We employ decision analysis (DA) to evaluate current policies' effectiveness and identify potential implementation risks, including external risks. We integrated literature, observational data, and stakeholder consultations to assess the impacts of ongoing school meal policies and the impact of these on children's nutrition. We assess existing school nutrition policies in Vietnam to assess their effectiveness in enhancing children's nutritional intake and identify potential risks to implementation. We generated a graphical impact pathway to express the case for the schools, including all costs, benefits and related risks of the existing investments. We follow up using Monte Carlo simulations to forecast nutrition outcomes and the cost reduction for health care. We further calculated the value of information for every input variable. Preliminary model results indicate how the internal (i.e. risks of implementation within the school and education systems) and external risks (e.g. school gate food, which is beyond the school's control) can potentially disrupt the intended impact of policies and, ultimately, child nutrition. Our model provides valuable insights for monitoring and adapting school meal policies in urban Vietnam. By emphasising evidence-driven policymaking, we showcase a method for addressing nutritional challenges in children's food environments through a rigorous and holistic analysis of potential policy interventions. We see enormous potential for evidence-driven and adaptive policymaking as a crucial tool in addressing the complex and multifaceted challenges of interventions to food environments and impacts on children's health.

Keywords: Decision analysis, food environment, health, nutrition policies, school meals

Contact Address: Thi Kim Anh Dinh, Hanoi University of Public Health, Fac. of Environmental and Occupational Health, Duc Thang, 10000 Hanoi, Vietnam, e-mail: dtka@huph.edu.vn

Poverty and food security impacts of sustainable intensification: Evidence from Ethiopia

Orkhan Sariyev, Jacob Asravor, Manfred Zeller

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

As sustainable intensification is a major pathway for improving agricultural productivity and reducing the environmental impacts of land use, the Government of Ethiopia and international development organisations have been promoting several practices and technologies for sustainable intensification. Rural households are likely to adopt a combination of various approaches and practices. This paper seeks to answer the question of how SI impacts poverty and food security among rural smallholders in Ethiopia by utilising three rounds of panel data from Ethiopia and concentrating on integrated soil fertility management (ISFM) technologies and their combination with conservation agriculture (CA). Using panel data from 376 farming households in Ethiopia from 2014, 2016, and 2019, this study gauges the poverty and food security impacts of ISFM technologies and their combined use with conservation agriculture practices. We employ the multinomial endogenous switching regression (MESR) model in addressing potential selection bias in farm households' uptake of these SI packages. We include two instrumental variables in the first stage of MESR: the standard deviation of rainfall between 1981 and 2018 and the historical average for the same period. We assume that historical rainfall patterns can play a role in technology choices and adoption decisions of smallholder farmers, but that they are not directly related to the outcomes of interest. We find significant positive effects of ISFM adoption in terms of increasing dietary diversity and food expenditure and reducing food insecurity. In terms of poverty, ISFM adoption decreases the probability of being poor, the poverty gap, and the severity of poverty. When combined with CA practices, we find that the effects are consistently larger for farmers who integrate ISFM and CA for all food security and poverty measures. Our findings strongly suggest that the adoption of ISFM technologies has significant positive implications for poverty reduction and improved food security. These benefits are likely to gain a considerable boost if ISFM technologies are applied together with CA practices.

Keywords: Conservation agriculture, integrated soil fertility management

Contact Address: Orkhan Sariyev, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Wollgrasweg 43, 70599 Stuttgart, Germany, e-mail: o.sariyev@uni-hohenheim.de

Individual-level drivers of food choices and diet quality among adolescents in urban West Africa: Evidence from Accra, Ghana

Janosch Klemm¹, Samuel Muli², Kolade Oluwagbemigun², Martin Parlasca¹, Aba Crentsil³, Deda Ogum³, Peter Quartey³, Amos Laar³,

Anna Lartey³, Christian Borgemeister¹, Ute Nöthlings²

¹University of Bonn, Center for Development Research (ZEF), Germany

²University of Bonn, Inst. of Nutrition and Food Sciences (IEL) - Nutritional Epidemiology, Germany

³University of Ghana, Inst. of Statistical, Social and Economic Research, Ghana

We sought to investigate the associations between five domains of individual factors (economic, cognitive, aspirational, situational and consumer behaviour) and diet intake of school-age adolescents in Accra, Ghana.

A cross-sectional survey among Junior High School students (n = 409, mean age 14.3 years \pm 1.28 (sd)) in Accra, Ghana (49.6 % male) was conducted. Data on diet intake using the Diet Quality Questionnaire methodology, knowledge, attitude, and practices and socio-economic background characteristics were collected. Diet intake indicators reflect food group diversity, namely, Food Group Diversity Score (FGDS), diversity of unfavourable (NCD Risk), diversity of favourable food groups (NCD Protect) and diet quality as adherence to Global Dietary Recommendations (GDR-Score). We define three diet types as "Strugglers" (low diversity across all food groups), "Champions" (predominantly consuming favourable food groups), or "Challengers" (predominantly consuming unfavourable food groups) based on food group diversity cut-offs. Data were analysed using multivariable linear regressions, with individual characteristics as predictors and diet quality indices as the outcome and multinominal logistic regressions to identify determinants of diet types.

Adjusting for other factors, students' total budget was positively associated with food group diversity (FGDS, $\beta = 0.12, 95 \%$ CI 0.09, 0.15), but inversely associated with diet quality (GDR-Score; $\beta = -0.07, 95 \%$ CI -0.11, -0.03). Positive attitude towards nutrition and healthy eating was inversely associated with unfavourable diversity (NCD-Risk Score, $\beta = -0.17, 95 \%$ CI -0.31, -0.03). Differences between Champions and Challengers were determined by attitude towards healthy eating (OR = 0.41; 95 % CI: 0.17, 0.99) and family practices (OR = 0.48; 95 % CI: 0.23, 1.00).

We provided evidence that higher food budgets were associated with higher diet diversity, but not with increased diet quality and that attitude, but not knowledge, was linked to better diet quality. Future studies should focus on the specific contribution of aspirational, situational, and behavioural factors in directing increased diversity towards favourable eating habits.

Keywords: Adolescent nutrition, diet diversity, diet quality, Global Dietary Recommendation (GDR) score, urban nutrition

Contact Address: Janosch Klemm, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: jklemm@uni-bonn.de

Improving urban consumers' access to safe vegetables: Case for factories and workers in Hanoi, Vietnam

Thi Sau Nguyen 1, Thi Tan Loc Nguyen 1, Simone Kathrin Kriesemer 2, Thi Thu Giang Luu 2, Cory Whitney 2

¹*Fruit and Vegetable Research Institute, Economics and Marketing Department, Vietnam* ²*University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany*

Low- and mid-income workers in Hanoi often depend on traditional markets to purchase reasonably priced vegetables. However, these markets lack formal food safety and quality controls, potentially exposing consumers to food safety and hygiene risks. Accessing safe vegetables poses a challenge for these workers, as supermarkets or farms with reliable safety standards are often financially inaccessible, lack market linkage (i.e., farms may not have contact with companies), or show limited interest (e.g., from supermarkets) in investing in worker market segments. Large factories that employ many low- and mid-income workers are interested in helping their employees access safe vegetables and expect investments to enhance worker health and satisfaction (better health, labour quality, worker loyalty). These companies are confronted with costs and risks related to investing in supporting vegetable access. Our NIFAM (Nutrition Intervention Forecasting and Monitoring) project aims to support decisionmaking for sustainable food environments and nutrition outcomes through transdisciplinary modelling methods. We collaborated with local stakeholders and experts to model three scenarios, wherein companies i) invest in having a safe vegetable selling point on the factory campus (FarmStand), ii) help to connect farmers with companies (ConnectFarm), or iii) choose not to take any action (DoNothing). We generated a graphical impact pathway to express the business case for companies, including all costs, benefits and related risks of the possible investments. We translated the model into a simulation in the R programming language. We used Monte Carlo simulations to forecast the Net Present Values (NPV) and calculated the value of information (VoI) for all input variables. Our model results indicate that companies should be willing to invest in farm stands on their premises. FarmStand offers the greatest benefit to companies' NPV and workers' health. Compared to DoNothing, the decision is worth a median value of about 11.600 USD y⁻¹. The ConnectFarm option is worth less than one-third of FarmStand. Narrowing the knowledge gap of high VoI variables (the farmer's revenue shared with the company and relative percent vegetable benefits if only connecting farmers and consumers) and monitoring the implementation pilots will help us reduce uncertainties and ensure our robust prediction results.

Keywords: Food environment, food safety, healthy diet, low-income

Contact Address: Thi Sau Nguyen, Fruit and Vegetable Research Institute, Economics and Marketing Department, Trau Quy town, Gia Lam district, Hanoi, Vietnam, e-mail: nguyenthisau.hd@gmail.com

Exploring Kenyan mothers' attention and child food choice through eye tracking in a natural environment

Ina ${\rm Cramer}^1,$ Iris ${\rm Schröter}^1,$ Diba Tabi ${\rm Roba}^2,$ Hussein Wario², Marcus Mergenthaler 1

¹South Westphalia University of Applied Science, Agricultural Economics, Germany ²Center for Research and Development in Drylands, Kenya

The empowerment of women in poverty-stricken northern Kenya is of great interest, to enhance their own and their families' nutritional status. It assists them in acquiring the resources and agency for their vital roles and functions in improving food security. Production of nutritious and affordable child food using traditional recipes constitutes a promising income-generating activity. If carried out by local women's groups, it can enhance food security and overall nutrition within their communities. Nevertheless, inadequate packaging makes it difficult to have access to the formal market. This study is part of a series of initiatives that aim to empower women's groups in northern Kenya. It aims at collectively creating appealing packaging designs to facilitate market access and penetration. Determining the key parameters driving attention and choice of local consumers at the point of sale is a challenging task. To address this challenge, a top-down (goal-directed), qualitative eve-tracking (ET) study was conducted in a real supermarket to explore the mechanisms of attention and choice. The study's methodology was based on "Guerrilla Testing", which originated in the field of user experience (UX). Four participants were equipped with eye-tracking glasses and given 1000 Kenyan shillings (approximately 7.60 US dollars) to select and purchase one or more child food products of their preference while thinking aloud. The number of fixations, voices, comments and the consumer's choice were recorded and analysed. The results of this study demonstrate that familiarity and acquaintance exert a profound influence on attention capture and purchasing decisions. Conversely, an outstanding shelf position exerts an influence on fixations, but not necessarily on purchasing decisions. The findings indicate that attentiongrabbing packaging designs are not sufficient to promote sales in the northern Kenyan context due to the aversion of lower-income consumers to risk and to trying new products. Consequently, local producers should devise strategies such as offering free tastings at the point of sale or direct sales in underprivileged areas to first enhance familiarity and trust in their child food products among consumers before they can successfully sell them in supermarkets.

Keywords: Child food, consumer choice, eye tracking, northern Kenya

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

Exploring sociocultural determinants of dietary behaviour among rural women of reproductive age in Amhara region, Ethiopia

Simegn Alamirew¹, Stefanie Lemke¹, Barbara Stadlmayr¹, Bernhard Freyer²

¹BOKU University, Sustainable Agricultural Systems, Austria ²BOKU University, Div. of Organic Farming, Austria

Women of reproductive age have specific nutritional requirements due to pregnancy and lactation. Little is known about the sociocultural determinants of dietary diversity among women of reproductive age. This study examines trends in dietary behaviour and the associated determinants of dietary diversity among women of reproductive age. A community-based cross-sectional study was conducted in 2019 in the Amhara region of Ethiopia. Using multistage systematic random sampling, the dietary diversity of n = 421 women of reproductive age was assessed by a 24-hour qualitative dietary recall. A descriptive analysis revealed characteristics of dietary behaviour and a chisquare test allowed identification of associated determinants of women's dietary diversity. It was found that only 26.8% of the women met the minimum dietary diversity score (MDD-W). The analysis, guided by the socioecological framework, showed that women's education, age, perception of nutritious diet, and frequency of consumption of animal-sourced foods, vegetables, and fruit were key determinants at the intrapersonal/individual level. Additionally, interpersonal/household level determinants such as, husbands' education, women's decision-making regarding food purchase/consumption, the family's actual eating occasion, and women's engagement in domestic and farming tasks were significantly associated with MDD-W. At the community level, access to clean water and especially cultural beliefs were significant determinants of MDD-W. Amharic proverbs and sayings prioritise men and strongly restrict women in food allocation. The majority (76.7%) of women of reproductive age practise frequent religious fasting, which relates to the institutional/national level. These findings underscore the need for a deeper examination of religious and cultural practices, to understand their impact not only on dietary diversity but also on women's lives.

Keywords: Dietary behaviour, dietary diversity, Ethiopia, sociodemographic and sociocultural determinants, women of reproductive age

Contact Address: Simegn Alamirew, BOKU University, Sustainable Agricultural Systems, Peter-Jordan-Strasse 76/1, 1190 Vienna, Austria, e-mail: simegn.alamirew@students.boku.ac.at

Home gardens, dietary diversity and household food security in urban informal settlements

Consolata Musita¹, Sophia Ngala², George Abong'², Tosin Akingbemisilu¹, Christine G. Kiria¹, Céline Termote¹

¹The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

²University of Nairobi, Food Science, Nutrition and Technology, Kenya

Malnutrition remains a global challenge. While Africa has made progress regarding the global nutrition targets, undernutrition coupled with overweight, and obesity persist. Informal settlements present unique challenges which exacerbates malnutrition, top on the list being poor dietary diversity and poor-quality diets. Increasing evidence shows that home gardens have the potential to improve food security and diets in rural areas but there is limited information in the urban informal settlements' context. The objective of this study was to analyse the correlations between home gardens, household food security and dietary diversity in urban informal settlements. The work builds on the baseline data from the HealthyFoodAfrica project in Kisumu (https://healthyfoodafrica.eu/).

The study, conducted in March/April 2022 in four informal settlements in Kisumu, Kenya, used a cross-sectional survey design with 510 randomly selected households. A semi-structured questionnaire captured information on presence/absence of a home garden. Household food security was assessed through Household Food Insecurity Access Scale (HFIAS). Dietary diversity (DD) data was collected for Women of reproductive age (WRA) and children 6–23 months using a quantitative 24-hr dietary intake recall tool. Logistic regression analysis was done while controlling for confounders.

Only 4.5% of households have home gardens, with significant differences across the four settlements (p = 0.03). DD was low for WRA (mean DDS= 4/10) and children (mean DDS=3/7). Having a home garden increased the chance of having higher DDS although no significant difference was observed for WRA (p = 0.2) and children (p = 0.3). Fruits and vegetables consumption was low (<20%). However, households with home gardens consumed more Vitamin A rich fruits and vegetables (WRA mean= 0.14 ± 0.36 ; child mean = 0.24 ± 0.44 ;) than those without (child mean= 0.15 ± 0.36 ; WRA mean = 0.08 ± 0.27) although not significant in both cases (child p = 0.3; WRA p = 0.3). HFIAS analysis showed households with home gardens have lesser tendency to be food insecure at 0.93 incidence rate ratio (0.83, 1.03 at 95% CI) than those without, although not significant (p = 0.2).

Findings show that promoting home gardens is an important pathway to improve food security and dietary diversity in food insecure settings such as informal settlements. Other research and policy implications are presented in the paper.

Keywords: Dietary diversity, food security, informal settlements, urban home gardens

Contact Address: Consolata Musita, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Nairobi Hub ICIPE Duduville Campus, 823-00621 Nairobi, Kenya, e-mail: m.consolata@cgiar.org

Navigating nourishment: Unveiling disparities between rural and urban food environments-a case study in Kenya

Nicanor Odongo¹, Irene Induli¹, Tosin Akingbemisilu¹, Irmgard Jordan¹, Michael Frei², Ramona Teuber², Céline Termote¹

¹The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

²Justus Liebig University Giessen, Inst. of Agronomy and Plant Breeding, Germany

Non-communicable diseases (NCDs) are increasing in both rural and poor urban areas, although urban areas are more affected. In urban areas, the greatest burden is borne by informal settlements, where one in five people are exposed to NCD risk factors due to unhealthy food environments. In rural areas, diets are increasingly transitioning toward more processed foods due to changing food environments. This study aimed to characterise the food environment in vulnerable urban and rural areas in Kenva. This will help provide context-specific evidence of the food environment that is useful for developing policies relevant for advancing safe and healthy diets. This study was conducted at two sites, Viwandani in Nairobi, representing the vulnerable urban, and Kiima Kiu in Makueni, representing the rural. GPS coordinates were collected from all vendors in the study area between October and December 2023. Vendors were categorised into 14 types, and the foods sold per vendor were listed and assigned to different food groups based on the 10 food groups scale used for the Minimum Dietary Diversity Score for Women (MDD-W) and unhealthy food groups such as snacks, sweetened beverages, oil and fats. Kiosks were the leading vendor type in both areas, followed closely by tabletop vendors (urban: kiosk, 38.5%; tabletop, 27.6%; rural: kiosk, 26.9%; tabletop, 24.47%). Kiosks had the widest diversity of food groups sold both in rural and urban areas. However, they also sold the greatest number of unhealthy foods - sugar-sweetened beverages and processed snacks. The percentage of vendors selling sugar-sweetened beverages was greater in rural areas (55.1%) than in urban areas (29.5%). Tabletop had the highest diversity of vegetables and fruits. Rural communities have higher exposure to ultra-processed foods, such as sugar-sweetened beverages and snacks, which increases their risk of developing NCDs. To support healthy eating, interventions promoting a healthy food environment need to be implemented in both rural and urban vulnerable populations.

Keywords: Food environments, food groups, food vendors, healthy foods

Contact Address: Nicanor Odongo, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, ICIPE Duduville Campus, 00621 Nairobi, Kenya, e-mail: n.odongo@cgiar.org

The role of international and national legal framework for the prevention and reduction of food loss and waste (FLW)

SRI OKTAVIA

Universitas Andalas, International Law, Indonesia

Currently, over 3 billion individuals globally lack access to a nutritious food. Approximately 690 million people are undernourished, and 2 billion people eat poorly, which results in micronutrient deficiencies and raises the risk of obesity and non-communicable diseases like diabetes, heart disease, and stroke. The agri-food system needs to be drastically changed in order to fulfil the human right to sufficient food in a sustainable manner and to offer everyone access to safe, cheap, and healthy meals. The fact that Food Loss and Waste (FLW) exists is proof of their present flaws. According to FAO, around 14 percent of the food produced is lost worldwide. Subsequently, food waste occurs at the retail and consumer distribution level. A report released by UNEP in 2021 states that 17 percent of the food produced is wasted worldwide. Further, around 8 to 10 percent of global greenhouse gas emissions are associated with FLW. The United Nations' 2030 Agenda for Sustainable Development Goals (SDGs) dedicated a specific target to the reduction of FLW, (target 12.3). Further, FLW also has a negative impact on the realisation of the human right to adequate food. This study aims to investigate the role of international and national legal framework for the prevention and reduction of FLW in order to achieve Sustainable Development Goals in Indonesia. To achieve the research objectives, several research questions have been addressed namely: (1) What are the roles of international laws/rules (hard law and soft law) for the prevention and reduction of FLW?, (2) How Indonesia adopted those rules into its national/domestic law?, and (3) What kind of model law for FLW prevention and reduction that can be applied in Indonesia? This research is empirical legal research and employs socio-legal approach. Data collection are applied trough document (web) sourcing and in-dept, face to face as well as online interview, with several informants from relevance institutions at the national level. Qualitative method are used to analysis data gathered, systematic literature review and content analysis are also employed.

Keywords: Food loss and waste, Indonesia, international legal framework, sustainable development goals

Contact Address: Sri Oktavia, Universitas Andalas, International Law, Jln Kalimantan Blok U/1 Wisma Indah I - Ulak Karang, Padang City, Indonesia, e-mail: srioktavia@law.unand.ac.id

Food literacy: Novel strategy to address hidden hunger among women in rural and urban Tanzania

Victoria Kariathi¹, Hadijah Mbwana¹, Constance Rybak², Safiness Msollo¹, John Msuya¹

¹Sokoine University of Agriculture, Dept. of Human Nutrition and Consumer Sciences, Tanzania

²Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany

Micronutrient deficiencies affect adult population in Tanzania. Due to the increased nutrient demands and physiological nature, women of reproductive age (WRA) are more vulnerable to micronutrient deficiencies. Despite the food production potential that Tanzania has, there is limited access to diverse and nutritious meals at household level. By fostering food literacy (FL), women can be empowered making healthy food choices, thus mitigating micronutrient deficiencies and breaking the malnutrition cycle. This study aimed at investigating the role of FL as a sustainable solution to combat hidden hunger among WRA in rural and urban Tanzania. A cross-sectional study was carried out involving 432 WRA from Mkuranga (rural) and Ilala (urban) districts in Tanzania. Data on FL, household dietary diversity (HDDS), dietary intake and sociodemographic characteristics was collected using a semi-structured questionnaire. Individual FL scores were categorised into three levels; excellent, sufficient, and limited. HDDS for 12 food groups was classified into three groups: low, medium, and high diversity. Individual dietary intake was estimated using 24-hours dietary recall. Information on FL were linked with HDDS and individual nutrient intake. Limited FL level was the highest (63.1%), with urban exhibiting significant higher mean scores. The mean HDDS was 6.54 with a significant lower mean in the rural compared to urban households. About 76% of households consumed high diversified foods. The mean daily iron, zinc, folate and vitamin A intake were 13mg, 7.84mg, $408.9\mu g$ and $669.84\mu g$, respectively which were below the recommended dietary intake (RDI) except for folate. About 21 %, 38 %, 41 % and 35 % attained the RDI for iron, zinc, folate and vitamin A, respectively. Correlation analysis shows a significant and positive relationship between individual FL scores and HDDS. Women with excellent FL had significantly (p < 0.05) higher HDDS compared to those with other levels. However, there was no significant relationship between daily micronutrient intake with individual FL score (p > 0.05). These findings show low levels of FL and high HDDS however, high HDDS does not explain adequate dietary intake. FL is needed to increase competences that could have the potential to increase awareness to consume micronutrient-rich foods among WRA in rural and urban Tanzania.

Keywords: women of reproductive age, dietary diversity, food literacy, micronutrient deficiencies, 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

Menugal farming: Sustaining food security, climate resilience, and cultural heritage in Borneo

Ivana Carynthia Ligo

Georg-August Universität Göttingen, International Agribusiness and Rural Development Economics, Germany

The current state of food security in Indonesia shows that the country still has due diligence in making sure its citizens have access to nutritional food. In response, the government has initiated a food estate programme designed to increase food reserves and enhance the local food system by opening agricultural land in several regions, including Borneo. The food estate programme was initiated in 2021 by targeting peatland areas but has faced a lot of constraints during its implementation, mainly related to unsuitable agricultural practices and conflicts related to land and social issues. Despite the huge coverage across Borneo and the strategic location, the Food Estate Programme did not show promising results in sustaining food security in Indonesia. Meanwhile, in the mountain area of Borneo, covered by a large area of peatland, a centuries-long agricultural practice passed on for many generations called Menugal. It is a traditional Meratus Dayaknese method for rice cultivation covering cultural practices, from choosing the suitable agrarian land until the harvest period. This study aims to dissect aspects of Menugal farming as indigenous knowledge and establish its connection to smart farming agriculture to assess its impact on food security, and climate resilience. A literature review is done through Google Scholar and Web of Science to identify each aspect of Menugal and analyse its role as a climate-smart agriculture. The expected result will show the extent of indigenous knowledge such as Menugal can provide information regarding sustainable agricultural approach to enhance food security and resilience towards climate change. This study is expected to inform policymakers about suitable agricultural practices aimed at integrating indigenous knowledge in the implementation of food estate programme as a concrete evidence of governments' efforts in promoting food sovereignty.

Keywords: Borneo, climate-smart agriculture, food estate, food security, indigenous knowledge, Menugal

Contact Address: Ivana Carynthia Ligo, Georg-August Universität Göttingen, International Agribusiness and Rural Development Economics, 37075 Göttingen, Germany, e-mail: i.ligo@stud.uni-goettingen.de

Linkages between food narratives and eating habits of low-income households in informal urban settlements in Nairobi, Kenya

SIGRUN PRENNER

BOKU University, IDR, Austria

Everybody needs food daily, but around 1.9 billion people worldwide are malnourished. Influencing people's food choices is complex and has limited effects when only considering physical and quantifiable factors. Eating habits are influenced by culture and beliefs which are social and emotional factors. Therefore, this qualitative research examining food choices in the low-income community of Mathare in Kenya. Investigations were conducted within the framework of the Theory of Planned Behaviour and are part of a research project of the International Crop Research Institute for the Semi-Arid Tropics. In the course of that project a Hip-Hop music video has been locally produced about food- related health issues and avoiding strategies. In this work, eleven participants who saw that music video have been individually interviewed twice within a period of one-and-a-half months. They were asked about their narratives they perceived around food before and after being exposed to the food related awareness creation. The findings show a significant effect on Food Attitudes, like participants stating that they started seeing interlinkages between food practices and human health. One finding of the Subjective Food Norms was, eating fried food with friends was not considered a treat anymore but bad for the health, and cooking together at home has been applied. A key finding from the Perceived Behavioural Control perspective was the courage of participants to point out mistakes to community members, to improve the food situation. These outcomes give first insights into the linkages between food narratives and eating habits, and how to induce a positive shift. To further tackle food behaviour change, more research is needed to understand the sustainable long-term effect of the educational music video on food narratives and eating habits.

Keywords: Food narratives, music for education and communication, behaviour change communication, eating habits, urban informal settlements

Contact Address: Sigrun Prenner, BOKU University, IDR, Vienna, Austria, e-mail: sigrun.prenner@outlook.com

Innovative solutions for food security: Examining the nutritive gardens systems in Burkina Faso

JUDITH HENZE¹, ROBERT DOULKOM², SILKE STÖBER¹ ¹Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Germany ²Forestry Department Zinaré, Burkina Faso

Burkina Faso, like many West African nations, is grappling with the adverse impacts of climate change, particularly evidenced through increasing occurrences of extreme weather events, notably droughts. Yet, the country's agricultural systems possess low resilience against these additional stressors. Consequently, there is an urgent need for straightforward, efficient, and cost-effective approaches to address this issue. One promising strategy is the implementation of so-called "Jardin Nutritif" or "Nutritive Garden", which focus on the intensive cultivation of *moringa* and baobab trees.

Nutritive gardens aim to improve the nutritional status, food security, and income of impoverished rural households. These gardens cultivate baobab and *moringa* plants, primarily for their nutrient-rich leaves. Baobab leaves, renowned for their high nutritional content, contain essential minerals and proteins crucial for vulnerable groups such as pregnant women and children. *Moringa* leaves, similarly nutritious, are rich in vitamins and minerals and are widely consumed across Africa.

The setup process, applying agroecological practices, typically overseen by a local forestry department technical officer, involves negotiations with landowners, demarcating the $1,5 \text{ m} \times 3 \text{ m}$ planting plots, soil preparation, and seed sowing. Each planting bed is exclusively dedicated to a single species, alternating between the two types. Once established, these gardens are typically managed by women's groups, who divide the responsibility for individual beds, but help each other out. Harvesting occurs approximately 45 days after sowing, with yields sold locally or processed for added value. Numerous NGOs have taken up this unique production system in their local projects, in particularly, the British NGO Tree Aid has set up over 200 nutritive gardens since 2017.

Evaluation sessions conducted with women's groups identified several benefits of nutritive gardens, including economic empowerment, food security enhancement, improved health outcomes, and social cohesion. However, challenges such as water availability, market reliability, and equipment deficiencies.

To enhance and expand this innovative system, NGOs and government bodies need to provide ongoing support beyond the initial setup phase, addressing challenges related to water availability, market access, and processing equipment. Identifying reliable buyers, exploring value-added products, and enhancing financial stability through cooperatives are crucial steps for the long-term sustainability of nutritive gardens.

Keywords: Agroecology, Burkina Faso, insensive farming, nutritive gardens

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

Peer education promotes mutual nutrition learning and agri-food entrepreneurship among women in the agro-pastoral areas of northern Benin

Ilimath Lafia, Georges Djohy

University of Parakou, National School of Statistics, Planning and Demography (EN-SPD), Benin

Peer-to-peer learning is known as a mutual training strategy that involves actors at the same level engaging in collaborative learning to acquire knowledge and develop skills needed to effectively solve societal issues. The study aims to analyse the impact of peer nutrition education - based on traditional foods co-developed with women - on their knowledge of and attitudes towards child nutrition and agri-food entrepreneurship among women. To achieve this, ten (10) women leaders who had taken part in a transdisciplinary research process that led to the co-development of four traditional foods (Kpankpannu, Wagaru, Boyri-Lamuni & Kaladje-Afuludje) in two districts in northern Benin (Banikoara and Nikki) were engaged in a peer nutrition education programme. They ran 150 community training sessions, with storytelling on good child feeding practices and cooking demonstrations, and 300 follow-up sessions with mothers of children. Participant observations were carried out during the learning sessions and a follow-up questionnaire was completed by the women leaders, who also used smartphones to take images and videos to capture what made sense to them during the learning sessions. The data was analysed for content and descriptive statistics. Preliminary results showed that peer nutrition education, through narrative communication, cooking demonstrations and dissemination of good practice and hygiene rules, had a positive impact by improving women's knowledge and child-feeding practices. All the 2,748 mothers of children reached by the programme, and in particular the 300 mothers followed closely, testified that they had changed the way they fed their children. Traditional foods, which were once on the verge of extinction, are increasingly seen as business opportunities for the promotion of sustainable healthy diets. Mothers of children expressed a strong desire for knowledge and learning about certain aspects of food that could help them to develop a business, in particular the packaging and labelling of traditional foods and their long-term preservation. A strong dynamic for the creation of income-generating activities based on traditional foods was observed among the women taking part in the mutual learning process. These results are useful for nutrition education policies and for empowering women through entrepreneurship in African agro-pastoral settings.

Keywords: Agro-food entrepreneurship, Benin, child malnutrition, mutual learning, peer nutrition education

Contact Address: Georges Djohy, University of Parakou, National School of Statistics, Planning and Demography (ENSPD), 03 BP 303, Parakou, Benin, e-mail: gdjohy@gmail.com

Unlocking nutritional frontiers: Analysing household diet quality and health outcomes in Nigeria

Tolulope Jerumeh

Nigerian Institute of Social and Economic Research, Agriculture and Food Policy Department, Nigeria

Diet quality has been identified as an immediate cause of malnutrition and a significant contributor to the global burden of Non-Communicable Diseases (NCDs). Thus, understanding the composition of diet quality and the extent to which it aligns with standard food-based dietary guidelines is crucial in promoting the health and overall wellbeing of households. This study examines the impact of household diet quality on health outcomes in Nigeria, utilising 2018/2019 General Household Survey data. Employing various techniques, including Minimum Dietary Diversity for Women (MDDW), Food Group Diversity Score (FGDS), Global Dietary Recommendation (GDR) score and the Probit model, the research assesses diet composition and its alignment with dietary guidelines.

Findings indicate prevalent consumption of grains, plantains, roots, tubers, meat, fish, poultry, other vegetables, and pulses, while dark green leafy vegetables and eggs are less consumed. The average GDR score is 10.5, reflecting halfway adherence to WHO recommendations. Urban households exhibit a slightly higher GDR score (10.66) than rural counterparts (10.50). Urban diets, rich in health-protective foods, also feature elements that contribute to Non-Communicable Diseases (NCDs).

Key drivers of diet quality include sex, marital status, education, total expenditure, and social class. The study shows that improved diet quality, estimated using the GDR score, significantly reduces the risk of NCDs in adults and lowers the prevalence of stunting among under-five children. These findings emphasise the need for policies and interventions to promote household diet quality in Nigeria. Targeted interventions and campaigns should be designed to promote healthier dietary choices and reduce the consumption of less healthy foods, especially in urban areas with a higher prevalence.

Keywords: Diet quality, dietary guidelines, GDR score, NCDs, stunting

Contact Address: Tolulope Jerumeh, Nigerian Institute of Social and Economic Research, Agriculture and Food Policy Department, PMB 5 UI Post Office Ojoo Ibadan, +234 Ojoo, Nigeria, e-mail: tolujerumeh@gmail.com

Food technology, food safety and consumer behaviour

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Harvest stage and method affect quality of amaranthus

Ogalo Baka Oluoch, Simon Muti, Jackson Mulinge, Elisha Otieno Gogo Pwani University, Crop Sciences, Kenya

There is limited information on the factors affecting postharvest losses in Coastal Kenva. The objective of this study was to determine the effect of the harvest stage and method on the harvest quality of amaranthus in Coastal Kenya. Two trials were done between April 2022 and September 2022 at Pwani University farm, Kilifi County, Kenya. The experiment was laid down in a randomised complete block design in a 2×2 factorial treatment arrangement, replicated three times. The factors studied were; harvest stage at two levels (6 weeks denoted S1) or 8 weeks denoted as S2) from planting and harvesting method at two levels (pinching denoted as M1 or uprooting denoted as M2). The treatments were arranged in all possible combinations. The parameters measured were; fresh weight, dry weight, total carotenoids, total chlorophyll, proximate composition (protein, fat, carbohydrates, energy, ash, and fibre) and macronutrients (K, Ca and Mg) and micronutrients (Fe and Zn). Data were subjected to analysis of variance and treatment effects were tested for significance at F-test at 5% level of significance. Amaranthus harvested at 8 weeks irrespective of harvest method had higher chlorophyll (22.9%), ash (43.2%) and Zn (54.4%) contents than those harvested at 6 weeks by pinching. Amaranthus harvested at 8 weeks after planting had higher fresh weight (37.1%), dry weight (17.7%), protein (34.3%), carbohydrates (25.8%), energy (15.6%), ash (22.5%), fibre (20.2%), carotenoids (38.9%), Fe (34.7%), and Zn (35.3%) contents compared with those harvested at 6 weeks. Amaranthus harvested by uprooting had higher dry weight (9.2%) compared with those harvested by pinching. This signifies that harvesting at 8 weeks irrespective of harvest method would offer higher nutritional value and yields of amaranthus.

Keywords: *Amaranthus* spp, maturity index, nutritional value, vegetable quality

Contact Address: Elisha Otieno Gogo, Pwani University, Crop Sciences, P.O. Box 195, 80108 Kilifi, Kenya, e-mail: e.gogo@pu.ac.ke

Effect of biodegradable modified film packaging on the quality and safety aspects of African nightshade

James Simon Chacha, Nadja Förster, Susanne Huyskens-Keil, Christian Ulrichs, Constance Rybak

Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany

African indigenous vegetables (AIVs) are of significant potential in achieving the UN SDG 1 (no poverty), SDG 2 (zero hunger) and SDG 3 (good health and well-being). While the production and commercialisation of AIVs provide income generating opportunities, their consumption has been linked to health benefits due to their high contents in micronutrients and health-promoting secondary plant metabolites. However, due to high perishability, inadequacies in postharvest handling has persistently led to higher qualitative and quantitative losses in AIVs along the vegetable value chain. As a result, AIVs storability which determines their distribution, marketability and consumption is adversely impacted. In the present study, the effect of biodegradable modified film packaging and storage conditions on microbiological quality and micronutrient/secondary plant metabolite contents of African nightshade (Solanum *nigrum*) leaves were investigated. African nightshade cultivated in greenhouse conditions was harvested eleven weeks after sowing, followed by storage in biodegradable film packaging bags at 6°C and 20°C for up to seven days. Quality evaluations of all treatments were conducted at the time of harvest (control), and on days 3 and 7 of storage. Leaf colour was evaluated using a chromameter, while total phenolic acids, flavonoids and ascorbic acid contents were evaluated using high-performance liquid chromatography. Microbial loads were determined using standard colony count protocols. Results indicated the use of biodegradable film packaging significantly reduced fresh weight losses compared to unpacked samples between days 3 and 7 of storage, with significantly higher losses in samples stored at 20°C. Leaf colour was better retained in biodegradable than unpacked samples, with the exception of biodegradable samples at 20°C (day 7) which showed increased leaf yellowing. Total phenolic acids and flavonoids content were maintained irrespective of the packaging conditions. However, the ascorbic acid content declined by at least 60% in both biodegradable and unpacked samples during storage. With respect to food safety aspects, the use of biodegradable modified film packaging did not reduce microbial counts, except the total bacterial and mould counts at 6°C storage. The present study indicates prospective utilisation of biodegradable film packaging to improve storability and minimise qualitative losses in African nightshade.

Keywords: African indigenous vegetables, bioactive compounds, biodegradable film packaging, food safety

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

Mycotoxin concentrations in rice are affected by chalkiness, grain shape, processing type and grain origin

Erasmus Tang¹, Geoffrey Onaga¹, Ortega-Beltran Alejandro², Falade Titilayo², Emmanuel Donkor³, Michael Frei³

¹*Africa Rice Center (AfricaRice), Côte d'Ivoire* ²*International Institute of Tropical Agriculture, Nigeria* ³*Justus Liebig University Giessen, Inst. of Agronomy and Plant Breeding, Germany*

Mycotoxins, especially those with carcinogenic potency, such as aflatoxin, fumonisin and zearalenone, as well as those with antinutritional effects, such as deoxynivalenol, are public health hazards. These problems are accentuated where food management practices, food quality control and regulatory systems from farm to plate are weak. Information on the prevalence of these mycotoxins in rice commercialised in markets in sub-Saharan Africa (SSA) is limited. The present study examined aflatoxin concentrations in 527 rice samples collected from 54 markets in five SSA countries in relation to grain quality characteristics, processing methods, and the origin of samples. Overall, 72% of the samples had detectable aflatoxin levels ranging from 3.0 to 89.8 ppb. Approximately 47% of the samples had total aflatoxin concentrations above 4 ppb [maximum residual limit (MLR) based on the European Union Standards] and were evaluated for co-occurrence with fumonisin, zearalenone, and deoxynivalenol. Multivariate analysis revealed that length to width ratio (p < 0.0001), mixed variety for width (p = 0.04), and chalkiness (p = 0.009) significantly influenced aflatoxin concentrations. Domestic rice had greater (p < 0.0001) aflatoxin levels than did imported rice. The aflatoxin levels in white rice were greater than those in brown (p = 0.02) and parboiled rice (p = 0.07). Slender grains had greater aflatoxin concentrations than did bold and medium grains (p < 0.0001). Total aflatoxin co-occurred with fumonisin and zearalenone in 18 and 40% of the samples respectively. None of the positive fumonisin samples exceeded 1 part per million (ppm) MRL while 30% of the positive zearalenone samples had concentrations exceeding the MRL of 75 ppb. These results revealed that almost 50 % of domestic and imported rice traded in SSA is at risk of being contaminated with mycotoxins if nothing is done. Possible strategies to mitigate mycotoxin contamination in rice include improving grain quality traits that might positively affect mycotoxin levels, employing improved management practices, especially proper drying and hermetic storage before and after milling. These findings provide valuable insights for both domestic and international actors in establishing and reinforcing regulations and management systems to mitigate mycotoxin contamination of rice.

Keywords: Africa, commercial samples, mycotoxin, processing method, rice quality, storage

Contact Address: Erasmus Tang, Africa Rice Center (AfricaRice), M'be Research Station, Bouake, Côte, e-mail: e.tang@cgiar.org

Food price elasticities of demand and choice: Implications for food and nutrition status in Tanzania

Eward Mushi¹, Roselyine Alphonce¹, Betty Waized¹, Mikidadi Muhanga², Niloofar Khalili³, Katharina Löhr³, Constance Rybak⁴

¹Sokoine University of Agriculture, Dept. of Agricultural Economics and Agribusiness, Tanzania

 2 Sokoine University of Agriculture, Dept. of Development and Strategic Studies, Tanzania

³Leibniz Centre for Agricultural Landscape Research (ZALF), Germany

⁴Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany

Malnutrition in all its forms is still prevalent in Tanzania, and its devastating health outcomes can not be overemphasised. Among the underlying causes of malnutrition are unhealthy food choices driven by food environment aspects such as availability, accessibility, food prices, and affordability. Interventions that target to influence these aspects could result in the improvement of food choices and ultimately food and nutrition status. However, with price volatility, the realisation of such an impact is jeopardised, pointing to a need for exploring how consumers substitute foods across different food groups as prices fluctuate. Understanding such consumption patterns could provide important information necessary for designing effective food and nutrition interventions. A multivariate regression analysis was applied to estimate the own and cross-price elasticities of demand for cereals, fruits, vegetables, fats, meat, sugar, milk, and roots and tuber foods. Data was collected from 567 consumers, randomly selected in Ilala and Mkuranga districts, in Tanzania. Results indicate all food groups exhibited a negative and less than one own-price elasticity, implying that price changes have a subdued effect on the quantity demanded, underscoring the inelastic nature of consumer demand for food. However, the levels of inelasticity varies among the food groups;, consumers have a relatively greater sensitivity to price fluctuations in fruits, vegetables, and meat compared to other food groups. Furthermore, results of crossprice elasticities show both distinct complementarity and competition between food pairs. Food groups such as sugar and milk, fruits and vegetables, meat and fruits, and grains and vegetables exhibited complementary relationships. Also, food group pairs that indicated a competitive relationship include vegetables and fats, fats and meat, grains and fats, and cereals and fats. The nature and degree of consumer responsiveness to price changes suggest a compromised food and nutrition status. It is recommended that policy attention should be directed towards the relatively more price elastic foods, such as fruits and vegetables which are considered healthier but are usually less consumed and compromised in case of economic shock, and more inelastic foods like sugar and fats which are considered unhealthy

Keywords: Food choice, food groups price elasticity, malnutrition, nutrition status, Tanzania

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

A comprehensive overview of West African soft cheese processing and conservation

Mahounakpon Wilfried Tossou¹, Matthew Atongbiik Achaglinkame², Linda Dari², Carole Nadia Adjouavi Sossa-Vihotogbé¹, Daniel Mörlein³

¹University of Parakou, Dept. of Nutrition and Food Sciences, Benin ²University for Development Studies, Agricultural Engineering, Ghana ³University of Göttingen, Dept. of Animal Sciences, Germany

Dairy products are vital sources of nutrition and livelihood for millions of people around the world. Because of the highly perishable nature of milk, cheese-making is an effective method of preserving its essential nutrients. In West Africa, cheese production is mainly a traditional craft, generally made from cow's milk by Fulani women. This cheese is characterised as a soft, unripened cheese with a moisture content of 50–60%. This paper aims to provide a comprehensive review of articles focusing on West African soft cheese (WASC) processing to better appreciate research gains and gaps in the subject area. A thorough literature search was conducted in electronic databases such as Scopus, Web of Science, PubMed and other sources (Google Scholar, ResearchGate). The literature search included keywords such as common and traditional names associated with WASC. The articles found were examined according to pre-established exclusion and inclusion criteria. Of 512 articles found, 57 met the inclusion criteria and were therefore considered. The findings revealed a similar cheese-making process across the West African regions including key steps such as heating, and addition of coagulant, although lacking standardisation regarding factors such as heating temperature and quantity of coagulant used. While the *Calotropis* procera plant appears to be the best-known and most widely used coagulant, some studies have tested alternatives such as *Carica papaya* leaves, lemon juice (*Citrus limon*), Moringa oleifera extract, tamarind fruit (Tamarindus indica), cereal soaking water and calcium chloride. The yield potential of traditional West African soft cheese varies according to the type and quantity of coagulant used and can be as high as 30%. West African soft cheese has a short shelf-life of around 1-2 days without any conservation treatment, which poses marketing problems. To date, preservation techniques remain traditional and involve operations such as boiling in salted water, drying or smoking/roasting. Further research into improving production processes and preservation methods will not only improve the quality of WASC but also broaden their distribution and export potential, to the benefit of local communities and beyond.

Keywords: Milk, Peul/Foula/Fulani, preservation, processing

Contact Address: Mahounakpon Wilfried Tossou, University of Parakou, Dept. of Nutrition and Food Sciences, Parakou, Benin, e-mail: wilfriedtossou581@gmail.com
Impact of crises on wheat availability in Syria: What are the effects on food security?

Rammah Zwan¹, Miroslava Bavorová¹, Kindah Ibrahim¹, Ghaith Ali²

¹*Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Czech Republic* ²*Tishreen University, Dep. of Agricultural Economics, Syria*

Agriculture suffered greatly due to the Syrian conflict that began in 2011 and caused severe social, political, economic, and environmental consequences for the entire country. The study aims to identify the situation of wheat production and food security in Syria and how it evolved between 2011 and 2021. A narrative review approach was used to summarise and evaluate articles from scientific journals. The literature search results are synthesised regarding the factors causing a decline in wheat production during the study period, including water shortages as environmental factors and displacement as social and economic consequences of conflict. Furthermore, quantitative data from secondary resources such as the Food and Agriculture Organisation (FAO) and national statistical abstract were used to evaluate the impact of the mentioned factors on wheat production and food security. The food security indicators employed include per capita wheat consumption (kg/person/year), food gap, self-sufficiency ratio, and import dependency ratio. Results show that the availability of wheat was not constant but decreased from 2013 to record its lowest value in 2016 when the available volume reached only 3,870 thousand tons; between 2013 and 2021, the average growth rate reached about -1.7. The most significant food gap for wheat was in 2021, when it reached about (-2456) thousand tons, due to the lack of production that year due to drought and the blockade, which resulted in the lack of fuel needed for irrigation. The amount of wheat available per capita for food decreased from 172 kg annually in 2011 to 132 kg annually in 2016. The availability of wheat per capita decreased at an average rate of -2.4. The research results have important policy implications as food security issues become crucial in Syria in latest years. Maintaining a stable wheat production, as the main staple food in Syria, is essential to keeping the food security at an acceptable level. This will require massive structural changes in the agricultural sector which needs further research to identify the policies needed to lead that change.

Keywords: Agricultural policies, conflict, food security, Syria, wheat production

Contact Address: Rammah Zwan, Czech University of Life Sciences Prague, Fac. of Tropical AgriScience - Dept. of Economics and Development, Prague, Czechia, 16500 Praha - suchdol, Czech Republic, e-mail: zwan@ftz.czu.cz

Investigating microbial fermentation effects on cassava leaf nutrient profile: A pre-processing method for human consumption

SELAMAWIT DEBELLE, ZIBA BARATIA, JOACHIM MÜLLER University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany

Cassava (Manihot esculenta) holds significant importance as a staple food in food-insecure regions of Ethiopia, primarily valued for its tuberous root. Moreover, cassava leaves are renowned for their high vitamin content and supplementary protein, offering a cost-effective solution to protein deficiency in local communities. However, their consumption is limited by elevated levels of cyanide, tannin, and potentially harmful phytin. In recent years, fermentation methods employing diverse probiotic microorganisms have emerged as crucial strategies to mitigate the presence of antinutritional factors and improve the nutritional profile of cassava leaves. This study aimed to evaluate the effectiveness of microbial fermentation in reducing cyanide and antinutrients, specifically tannic acid and phytic acid, in cassava leaves. Fresh cassava leaves sourced from the University of Hohenheim greenhouse underwent fermentation under various conditions: natural fermentation, fermentation with Saccharomyces cerevisiae (S.c), fermentation with Lactobacillus acidophilus (La), and a co-culture of both inoculums, over 15 days at 30°C. Results indicated a significant reduction in cyanide content across all fermentation conditions, with the highest decrease observed in samples fermented with La, showing a reduction of 66.92%. Tannin content experienced a notable decline during the initial 7 days of fermentation, while total phenolic content exhibited a significant increase, particularly in samples subjected to co-culture fermentation, showing a rise of 69.65 %. In conclusion, microbial fermentation holds promise in mitigating cyanide and antinutrient levels in cassava leaves, potentially detoxifying them to a degree suitable for human consumption. Further exploration and optimisation of this technique are recommended to enhance its efficacy as a pre-processing approach for improving the safety and nutritional quality of cassava leaves. Continued research into optimal fermentation conditions and probiotic microorganism selection could unlock the full nutritional potential of cassava leaves while ensuring their safety for widespread consumption.

Keywords: Antinutrient composition, health benefits, human consumption

Contact Address: Selamawit Debelle, University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, 70593 Stuttgart, Germany, e-mail: yeselamt@gmail.com

Phenolic acids play a vital role in compatibility of *Fusarium oxysporum* f.sp. *strigae* biocontrol ability with legume intercropping for striga management in maize

Mekuria Wolde Assena, Frank Rasche

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

Striga is the major threat to cereal production in sub-Saharan Africa. In this work, we examined the compatibility of legume intercropping with the biological control approach for efficient Striga management. The effect of phenolic acids (PA) and crude root exudates from three legume crops on Fusarium oxysporum f.sp. strigae (Fos) FK3 were investigated. The result showed that some PA inhibited Fos mycelial growth and spore germination. Piperonylic acid and Cinnamic acid caused the strongest inhibition of Fos at 1mM and 0.5mM concentration. Others like p-coumaric, trans-ferulic, benzoic and 3,4-dimethoxybenzoic acid caused a slight inhibition at higher concentrations. All the other tested PA at all concentrations didn't cause inhibition. The crude root exudate collected from Crotalaria caused strong Fos mycelial inhibition at 1 mg ml^{-1} and 0.5 mg ml^{-1} while the exudate from *Desmodium* and *Mucuna* didn't cause inhibition on Fos mycelial growth. The result from pot experiment showed that emerged Striga count per pot was significantly lower in all treatments compared to the control (Striga only). However, the lowest Striga count was noticed on pots with *Desmodium* + Fos, which was not significant with the negative control (no *Striga*), unveiling the strongest Striga suppression. Significantly lower maize dry biomass was noticed on pots with Mucuna + Striga and control (Striga only). OPCR-based Fos abundance measurement revealed that Fos gene copy number was more abundant on pots with the presence of legumes, indicating its proliferation is not affected by legumes. LC-MS/MS analysis of PA from rhizosphere soil depicted that PA concentration is influenced by the cropping system. P-coumaric acid was detected in higher concentrations in all treatments. Relatively, a slight increase in some of the PA were detected in maize + Striga than the negative control (maize alone), suggesting Striga infestation triggered PA exudation from maize. Interestingly, Piperonylic acid was detected only in treatments that have Mucuna plant. Generally, legume intercropping with maize didn't inhibit the proliferation of Fos in the rhizosphere soil, indicating their integration could be compatible Striga management options.

Keywords: Fos proliferation, integrated Striga management, piperonylic acid

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

Impacts of the integrated rice-fish farming system technology on food and nutrition security of small-scale farmers in developing countries: An application of marginal treatment effect model

Aminou Arouna¹, Rachidi Aboudou¹, Inoussa Akintayo², Roger Ahouansou²

¹*AfricaRice*, *Côte d'Ivoire* ²*AfricaRice*, *Liberia*

Food insecurity and child malnutrition remain persistent problems in sub-Saharan Africa. In this study, we analyse the heterogeneity in the impacts of integrated rice-fish farming system technology (IRFFST) on welfare indicators such as the quantity of fish consumed in the household, food and nutrition security, and poverty reduction in Liberia. We employ the marginal treatment effects (MTE) approach to estimate the treatment effects heterogeneity and policy-relevant treatment effects (PRTE) on the cross-sectional survey data of 967 rice farmers in Liberia. The findings show substantial heterogeneity in the benefits from the adoption of IRFFST for both observed and unobserved household characteristics. Among the determinants of adoption, the key determinants are access to credit, access to irrigation in the lowlands, farm size, and access to extension services. The empirical results show that the adoption of the IRFFST significantly reduces household food insecurity, increases the quantity of fish consumed in the household, and increases household dietary diversity, but reduces the poverty headcount of households at the lower level of unobserved resistance to adoption. On average, a random farmer selected from among the rice farmers had their food consumption score increase by 8.28 units. In addition, on average, a random farmer selected among the rice farmers had increased the quantity of fish consumed in their household per month by 7.92 kg (equivalent to a 31% increase) due to the adoption of IRFFST. Overall, promoting IRFFST technology is important to improve food and nutrition security and the welfare of rural people, especially for marginalised poor indigenous smallholder rural farm households.

Keywords: Adoption, Africa, food security, impact, integrated rice-fish farming System technology

Contact Address: Rachidi Aboudou, AfricaRice, Policy, Innovation Systems, and Impact Assessment Program (PII), Bouake, Côte d'Ivoire, e-mail: rachidiaboudou@gmail.com

Exploring the nutritional and technological potential of sorghum in wheat-based breads

ELEONORA CHARLOTTE PICHLER, BENJAMIN ILLMER, REGINE SCHÖNLECHNER BOKU University, Department of Food Science and Technology, Austria

Climate change challenges have heightened the need for alternative crop cultivation methods. Sorghum, known for its resilience in adverse conditions, emerges as a promising grain that thrives in both traditional (India, African countries) and Western regions. Sorghum's kafirins, the prolamin fraction, though, can crosslink with polyphenols and starch, potentially reducing its digestibility. This study aimed to assess the potential of sorghum in the Western diet by investigating its nutritional attributes and technological properties. Eight sorghum varieties cultivated in Austria, namely Arabesk, Armorik, Arsky, Ggolden, Huggo, Icebergg, Kalatur, and PR88Y92, were analysed for total phenolic content (TPC), antioxidative activity, and *in vitro* starch and protein digestibility. Three varieties (Huggo, Icebergg, Kalatur) were selected for baking trials to evaluate their baking properties and the impact of TPC. These varieties differed in their pericarp colour (red, white, white) and TPC (high, medium, low, respectively). Substituting 40% of wheat flour with sorghum flour in a standard western-style bread recipe, the resulting breads were examined for physical characteristics, such as baking loss, crust and crumb colour, crumb firmness and relative elasticity, pore properties of the crumb, and specific volume. Additionally, the TPC, antioxidative activity, and *in vitro* starch and protein digestibility were analysed. The substitution of wheat flour with 40% sorghum flour resulted in a decrease in specific volume and relative elasticity, but a significant increase in TPC and antioxidative potential, regardless of the variety. A significant disparity in total phenolic content (TPC) and antioxidative activities was noted among the sorghum varieties, contrasting with the consistent findings for *in vitro* starch and protein digestibility. The relationship between total phenolic content (TPC) and in vitro protein digestibility was clearly inverse in both breads and flours, while no such association was found between TPC and *in vitro* starch digestibility. This research demonstrates the potential of enhancing TPC in wheat bread by incorporating sorghum, albeit with a trade-off of reduced in vitro protein digestibility. The study enhances our understanding of how different sorghum varieties influence the quality of sorghum-wheat breads, providing valuable insights for the development of nutritious and functional wheat-based products.

Keywords: Digestibility, protein, sorghum, TPC, western-style bread

Contact Address: Eleonora Charlotte Pichler, BOKU University, Department of Food Science and Technology, Muthgasse 18, 1190 Vienna, Austria, e-mail: eleonora.pichler@boku.ac.at

Nutritional composition and antinutritive compounds in Moringa oleifera leaf accessions from Kenya, Tanzania and Mali

Boniface Mwami¹, Zbynek Polesny¹, Prasad Hendre², Alice Muchugi²

¹Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Czech Republic ²The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya

Inadequate nutrition is one of the leading causes of poor health globally, affecting mainly sub-Saharan Africa, which is persistently faced with malnutrition and starvation. Moringa oleifera is a nutrient-dense food with the potential to attenuate the aforementioned challenges. This study, therefore, aimed to compare the nutritional and anti-nutritional composition of its leaves across different agroecological zones in Kenva, Tanzania, and Mali. The leaf samples were collected and dried separately at 55 °C for 24 hours. The homogenized powder was analysed for proximate composition following the AOAC standard methods, while the antinutritive compounds, namely cyanogenic glycosides, carotenoids, and phytates, were quantitatively analysed using the HPLC-UV method. The analysed data revealed significant (p < 0.05) differences in nutritional and antinutrient content across the geographical areas. The highest protein content was observed in Mtongwe (30.24. + 0.24%) and the lowest in Sikaso (19.07 + 0.44%). The carbohydrate content was highest in Arusha (60.56 + 0.48%) and lowest in Mtongwe (40.90 + 0.17%). Matsangoni had the highest fibre content (11.76 + 0.26%) while Arusha had the lowest (9.47 + 0.42%). Cyanogenic glycoside (g/100g) was highest (0.0164 +0.001) and lowest (0.0059 + 0.001) in Kitui and Malindi, respectively. The highest phytate content $(3.46 \pm [0.06] \text{ g kg}^{-1})$ was found in Mtongwe and the lowest in Kounikoro $(1.51 \pm 0.11 \text{ g kg}^{-1})$. Matsangoni recorded the highest content of carotenoids (mg/100 g) which was (10.44 + 1.10) compared with Kounikoro, which had the lowest (6.38 + 0.48). It was evident that, while the leaves are well endowed with nutritional attributes and smaller amounts of anti-nutrients, variations in the quantity of the anti-nutrients could indicate genetic differences that could be explored.

Keywords: Africa, anti-nutrients, Moringa, phytonutrients, supplemental food

Contact Address: Boniface Mwami, Czech University of Life Sciences, Crop Sciences and Agroforestry, Kamycka 129165 00, Prague, Czech Republic, e-mail: mwami@ftz.czu.cz

Comparative biochemical, anti-oxidative and sensory attributes of freeze-dried and air-dried 'chandler' strawberry fruit

Maryam Fatima¹, Sami Ullah¹, Hafiz Nazar Faried¹, Gulzar Akhtar¹, Kashif Razzaq¹, Ishtiaq Ahmad Rajwana¹, Asif-Ur Rehman², Dua Zahra Khan¹

¹*MNS-University of Agriculture, Dept. of Horticulture, Pakistan* ²*Agriculture Dept., Horticultural Research Station, Sahiwal, Pakistan*

Strawberry fruit is praised for refreshing taste and rich nutritive value but with high perishable fruit quality after harvest. Ultimately, processing techniques like drying reduces rapid postharvest quality and nutrition losses in strawberry. However, various drying techniques affect the produce quality and nutrition. So, a study was executed to compare the efficacy of two fruit drying techniques for strawberry fruit. Fruit of 'Chandler' strawberry were harvested at commercial maturity and were subjected to freeze drying (-60 °C for 24 hours) and hot air drying (60 °C in and electric dehumidified dryer for 24 hours). In another experiment, in addition to that efficacy of fruit cut techniques were also evaluated for both drying techniques. Strawberry fruit were cut into four different types of cut (T1= whole fruit of strawberry, T2= strawberry fruit without pedicle, T3= fruit pedicle + cortex removed, T4= fruit pedicle + cortex removed & fruit cut into half) prior to drying. The dried fruit were investigated for various biochemical [total soluble solids (TSS), titratable acidity (TA), ascorbic acid contents], anti-oxidative [total phenolic contents (TPC), total anti-oxidative activity, activities of superoxide dismutase (SOD), catalase (CAT) and peroxidase (POD) enzymes] and sensory attributes (colour, taste, texture and overall acceptability). The results indicated that irrespective to type of cut, freeze-dried strawberry exhibited comparatively better fruit quality attributes as compared to air-dried strawberry. Freeze-dried strawberry retained higher anti-oxidative attributes including ascorbic acid contents (63 mg 100 g⁻¹ FW), TPC (111 mg GAE g⁻¹ FW), total anti-oxidative acidity (83 inhibition % DPPH) and exhibited better fruit sensory characteristics fruit texture (7.9 score), flavor (8.3) and overall-consumer acceptability (8.9 score) as compared to air dried strawberry fruit. The fruit cut method T4 (fruit pedicle + cortex removed & fruit cut into half) improved drying efficiency both for freezedrying and air drying method. Conclusively, freeze-dried strawberry retained significant better fruit quality attributes as compared to air dried strawberry.

Keywords: Dehydration techniques, fresh cut fruit, fruit preservation, fruit quality

Contact Address: Sami Ullah, MNS-University of Agriculture, Dept. of Horticulture, 60000 Multan, Pakistan, e-mail: sami.ullah1@mnsuam.edu.pk

Effects of *Tithonia diversifolia* on seed germination, growth parameters and the nutrient content of soybean

Joseph Blaise Dongmo Lekagne¹, Edouard Nantia Akono², Angeline Ngamassi Konchipe¹, Philippe Stephane Kamgang Kiage², Ruth Ngum Che², Julienne Nguefack¹

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

Conventional farming relies heavily on chemical inputs such as synthetic fertilisers. Yet, their negative impacts on human and environment health have been well documented. Tithonia diversifolia is a plant that could be used as an organic fertiliser due to its high content of nitrogen. This study investigated the effect of T. diversifolia extract at different concentrations and incubation time on the germination of soybean seeds and the effect of T. diversifolia leaves applied in powder form or composted on sovbean growth and nutrient content. We employed a split plot design with three replicates made up of four blocks. Each block was amended (main factor) either with *T. diversifolia* compost (150 g plant⁻¹), powder (40 g plant⁻¹) or the synthetic fertiliser NPK (10 g plant⁻¹) respectively, followed by spraving (second factor) with same fertiliser at 20 gl⁻¹, 20 gl⁻¹ and 2 gl⁻¹ or water every two weeks after one-time amendment. The control block received no amendment and was sprayed with water. The top of paper method was used to evaluate the effect of T. diversifolia extracts on soybean seed germination at different incubation times. Growth parameters including plant height (cm), number of pods per plants, seed weight per m^2 (g) and grain yield (tha⁻¹) were recorded. The soybeans were harvested four months after sowing and analysed for crude protein, lipids, and fibre contents using the Kjeldahl, Bourely, and Weende methods respectively. T. diversifolia extract at 1 g l-1 and three hours incubation time produced the highest percentage seed germination (72%). T. diversifolia compost produced the best growth (p < 0.05) in terms of plant height (63.3±3.1), number of pods per pant (83.7 ± 5.1) , seed weight per m² (357.7 ± 45.5) , grain yield (3.6+0.5) as compared to the others treatments. The highest crude protein content (31.2%) in the soybeans was observed in the *T. diversifolia* compost treatment*T. diver*sifolia powder yielded higher lipid (31.4%) and fibre (5.9%) contents as compared to other treatments. Thus, T. diversifolia extract can be used as a bio-stimulant to optimise the germination of seeds like soybean while its leaves whether powdered or composted are a promising organic fertiliser for promoting organic crop production in Africa.

Keywords: Growth parameters, nutrient content, organic fertiliser, soybean, *Tithonia diversifolia*

Contact Address: Joseph Blaise Dongmo Lekagne, University of Yaoundé 1, Dept. of Biochemistry, Ngoa-Ekele 812, Yaoundé, Cameroon, e-mail: blaiselekagne@yahoo.fr

Phosphorus fertiliser management on grain quality and seed phytic concentrations of black rice for consumption and production

Aung Zaw Oo, Hidetoshi Asai, Junichiro Marui, Toshiyuki Takai, Hiroki Saito

Japan International Research Center for Agricultural Sciences, Japan

Black rice, known for its antioxidant properties, is becoming increasingly popular due to its nutritional value, especially in Asian tropical regions. It is known for its antioxidant properties, but its productivity is often limited by soil infertility, particularly by soil phosphorus (P) deficiency. However, the effect of soil P availability on grain quality has not been fully understood.

A recent trial was conducted in which different rates of P fertiliser (ranging from 0- 1300 mg pot^{-1}) were applied to P-deficient soils. The results showed that soil P deficiency reduced grain yield, which increased with higher soil P availability until it plateaued at an optimal P rate of 250 mg pot⁻¹. Conversely, reduced soil P availability enhanced the grain quality, resulting in increased mineral content (Fe and Zn) and total flavonoid content. As soil P availability increased beyond the optimal P rate, these nutritional parameters declined. Similarly, seed phytic acid (PA) content, which is an antinutritive agent that inhibits the absorption of essential minerals, increased from 16 mg g⁻¹ to 35 mg g⁻¹ as soil P availability increased. This increase persisted even beyond the optimal P rate. Therefore, it is essential to manage soil P optimally to maximise yield while maintaining nutritional quality and mitigating seed PA accumulation in black rice for human consumption. Moreover, seed PA serves as a P source for initial growth and plays a crucial role in early seedling vigour. However, low PA seed had reduced seedling vigour and increased ethylene production in response to P stress, a key mechanism modulating seedling growth. Conversely, high PA seeds had improved root development and physiological processes, leading to increased seedling vigour and P uptake. Furthermore, a combination of high PA seed and external P supply significantly improved seedling growth. In conclusion, optimal P management enhances the nutritional quality of black rice and maintains optimal yield with low PA levels. This study also emphasises the importance of seeds with high PA in enhancing early vigour and subsequent rice growth, providing useful insights for rice growers and consumers who seek to obtain the maximum nutritional value from black rice while maintaining its high yield.

Keywords: Antioxidants, black rice, mineral content, phosphorus

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

Milk quality based on soil fertility and pasture composition in Fleckvieh systems in the Peruvian Amazon

Deysi Yenny Ruiz Llontop¹, Segundo M. Portocarrero-Villegas¹, Joe Mantilla-Oliva², Flor Mejía-Risco¹, Khaterine Salazar-Cubillas³, José Américo Saucedo-Uriarte¹

¹Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Instituto de Investigación en Ganadería y Biotecnología, Peru

²GENEX CDP PERU, Global Development, Peru

³Christian Albrechts University of Kiel, Institute of Animal Nutrition and Feed Science, Germany

This study aims to assess the relationship between milk quality with soil fertility and pasture nutritional composition in ten Fleckvieh bovine production systems distributed across four provinces within the Amazon region: Chachapoyas (system I; n = 2), Bongara (system II; n = 4), Rodriguez de Mendoza (system III; n = 2), and Utcubamba (system IV; n = 2). The chemical compositions of milk (crude fat, crude protein, lactose, total solids, and fat and protein corrected milk), bromatological composition of pasture (dry matter, humidity, crude ash, crude fat, crude fibre, crude protein, nitrogen-free extract, gross energy, and dry matter digestibility), and soil parameters (pH, electric conductivity, phosphorus, potassium, carbon, organic matter, and nitrogen) were analysed and compared using Duncan's Multiple Range Test across systems (n = 4). Pearson's correlation coefficient was then calculated to assess the strength and direction of the relationships (n = 10). No significant differences among systems were observed between pasture nutritional composition, milk, and soil parameters such as pH, electrical conductivity, phosphorus, and potassium. However, statistical differences between soil concentrations of carbon, organic matter, and nitrogen were found between systems. Strong correlations were identified between pasture partial dry matter and milk fat (r = 0.62), as well as with milk crude protein (r = 0.61). Moderate correlations were observed between pasture partial dry matter and milk total solids (r = 0.52), milk lactose and soil phosphorus (r = -0.44), milk crude protein and soil potassium (r = 0.40), electric conductivity and pasture total dry matter (r = 0.44), soil potassium and pasture crude ash (r = 0.49), soil carbon and pasture crude fat (r = 0.49)(0.40), and soil organic matter and pasture crude fat (r = 0.40). This suggests that the combined makeup of pastures and soil can influence the nutritional profile of milk in these systems. Thus, implementing effective soil and pasture management strategies could enhance the overall productivity of these regimens.

Keywords: Amazon region, dual-purpose system, pastoral systems, pasture quality, rainforest

Contact Address: Deysi Yenny Ruiz Llontop, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Instituto de Investigación en Ganadería y Biotecnología, Jr. Triunfo Cuadra 2, 01001 Chachapoyas, Amazonas, Peru, e-mail: yennyruiz2211@gmail.com

Improving the quality of pearl millet and wheat flour composite bread by optimising process parameters

Aregash Mamo Gizaw¹, Metadel Kassahun Abera¹, Hirut Assaye Cherie¹, Minaleshewa Atilabachew Gebretsadik¹, Anastasia Kanellou², Lara Allen³, Tadesse Fenta Yehuala¹, Tadelle Nigusu Mekonnen²

¹University of Gonder, Chemical Engineering, Ethiopia ²University of West Attica, Food Science and Technology, Greece ³Centre for Global Equality (CGE), United Kingdom

Bread is traditionally made from wheat flour. However, there are challenges in using wheat for bread development, such as low yield, the inability to resist drought, and low pest resistance in developing countries. Millets, which are underutilised cereals on the other hand can overcome the above-mentioned challenges and hence be used to make bread by mixing with wheat. However, using millet for bread development has some issues due to the presence of anti-nutritional factors (phytate and tannin). The overall process includes cleaning, washing the millet, germination (malting), drying, grinding, and dough preparation for making bread. The germination effect on the anti-nutritional contents was investigated by varying the germination time (1, 2, and3 days) and germination temperature (25, 30, and 35 $^{\circ}$ C). After the germination conditions were optimised, the effect of flour size (150, 250, and 350 μ m) and the mixing ratio of millet flour with wheat (0, 10, 30, and, 50%) on antinutritional components and the quality of bread were analysed. The phytate and tannin content of raw pearl millet were 689.6 mg/100 g and 834.7 mg/100 g, respectively. The lowest phytate and tannin content for pearl millet was 95.5 mg/100g and 105.2 mg/100 g, respectively, at 30 °C for 3 days of germination. This result shows that both temperature and time during the germinating process have a significant impact on both phytate and tannin content reduction. The optimum mixing ratio (millet to wheat) and particle size were 10:90 and 150 micrometers, respectively, for pearl millet with wheat flour composite bread, which shows mixing ratio and particle size have a significant effect on the reduction of phytate, and tannin content and enhance the quality of bread from pearl millet, and wheat composite bread. Germination time, temperature, mixing ratio, and particle size appeared to be promising food processing methods for improving the nutrient and energy densities of pearl millet, and wheat composite flour bread, which enables the introduction of the utilisation of underutilised and environmentally shock-resilient cereals like pearl millet, and this could be a means to alleviate the hidden hunger in developing countries, including the global south.

Keywords: Bread, germination, mixing, pearl millet, phytate, tannin

Contact Address: Tadesse Fenta Yehuala, Bahir Dar University, Fac. of Chemical and Food Engineering, Kebele 10, Bahir Dar, Ethiopia, e-mail: tadeyfenta@gmail.com

Evaluating standard procedures for instrumental textural analysis of steamed potato: Relationship with sensory parameters

Mariam Nakitto¹, Mukani Moyo², Thiago Mendes², Brian Balikoowa³, Reuben Tendo Ssali¹, Ayetigbo Oluwatoyin⁴, Christian Mestres⁴, Dominique Dufour⁴

¹International Potato Center (CIP), Food Laboratory, Uganda ²International Potato Center (CIP), Kenya ³National Agricultural Research Laboratories (NARL), Uganda ⁴French Agricultural Research Centre for Intern. Developm. (CIRAD), France

Consumer preference for boiled potato in Uganda has been assessed to be prevalently based on soft (hardness) and mealy texture. However, harmonised standard procedures have not been hitherto developed to characterize the texture of boiled potato instrumentally in SSA. The RTBBreeding[®] project focussed on developing discriminant and sensory-correlated procedures based on comparative analyses of Extrusion, Penetration and Texture Profile Analysis (TPA) techniques for mid-throughput evaluation of texture of steamed potato from potato varieties. Tubers of nine popular landrace varieties cultivated in Kabale and Rakai districts of Uganda were used. The tubers were cut into 25 mm cubes, steamed for 15 min in banana leaves and analysed using a calibrated TA-XT texture analyser under standard conditions (Extrusion: test speed 1 mm s⁻¹, strain 80 %, 5-blade grid Ottawa cell; Penetration: test speed 1 mm s⁻¹, distance 10 mm, 60° cone probe; TPA: test speed 1 mm s⁻¹, distance 5 mm, wait period 5 s, 75 mm cylindrical plate) at about 25 °C. For descriptive sensory analysis, twenty random tubers from each variety were steamed for 40 min and evaluated in duplicate by trained panellists for eleven selected sensory parameters on a 11-point scale ranging from 0 (minimum intensity) to 10 (maximum intensity). Results show that Area under curve/Extrusion work (73-236 N.mm), Maximum force/ hardness (6-17 N), and End force (6-15 N) were the more discriminant textural parameters for extrusion. Maximum force, End force and Extrusion work significantly correlated with sensory Moisture release and Hardness by hand. The discriminant textural parameters for penetration were Area under curve/ Penetration work (6-21 Nmm) and Maximum force/ hardness (2-6 N). Significant correlations exist between penetration Hardness and Area under curve and the sensory Hardness by hand, fracturability, cohesiveness, and smoothness. Finally, the more discriminant textural parameters for TPA were Hardness (20-52 N), Gumminess (5-19 N) and Chewiness (5-18 N). There are significant correlations between TPA Adhesiveness and sensory moisture release and mealiness. Among the methods, the penetration method was more preferred as it correlated most with sensory evaluation, while TPA was least correlated with sensory.

Keywords: Extrusion, sensory analysis, steamed potato, texture profile analysis

Contact Address: Ayetigbo Oluwatoyin, French Agricultural Research Centre for International Development (CIRAD), UMR Qualisud, 34398 Montpellier, France, e-mail: oluwatoyin.ayetigbo@cirad.fr

Socio-economic development and the food environment

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Farmer participation on the Ghana commodity exchange: Does the risk attitude of resource-poor farmers matter?

Yaw Bonsu Osei-Asare 1 , Solomon Koomson 2

¹*University of Ghana, Dept. of Agricultural Economics and Agribusiness, Ghana* ²*Ghana Cocoa Board, Technical (CHED), Ghana*

The Ghana Commodity Exchange (GCX) was established as an alternative market platform that connects smallholder farmers in Ghana to the agricultural and financial markets throughout the West African subregion to ensure that farmers receive competitive prices for their products and can supply high-quality products that satisfy the country's nutritional needs. However, the number of farmers trading on the Exchange is low, likewise, the volumes of maize and soybean traded on the Exchange when compared to the volumes produced in Ghana and traded on the open market. Aside from the issue of information asymmetry and increased transaction costs that limit access to the Exchange, do the risk attitudes of these resource-poor farmers play a role in their participation in the Exchange? This study used a multistage sampling technique to sample 600 farmers (250 sampled farmers traded on the GCX, whereas 350 did not) from five (5) administrative regions in Ghana where the GCX has its warehouses located. The self-assessment test to elicit the risk attitude of farmers participating in the GCX was employed. The selfassessment test utilised a seven-point Likert scale from "not willing to take a risk" to "very willing to take a risk" to assess the risk attitude of farmers participating on the GCX. Based on the self-assessment test, the study finds that farmers are moderately risk averse. Older farmers are less likely to take risks, whereas male farmers are more inclined to take risks, although the results showed no statistical significance at the 5% level for either variable. More experienced farmers were less willing to take risks by participating on the Exchange. Farmers therefore need to be educated and provided incentives to participate on the Exchange to enhance their incomes and livelihoods.

Keywords: Farmers, Ghana commodity exchange, livelihoods, risk attitudes, self-assessment

Contact Address: Yaw Bonsu Osei-Asare, University of Ghana, Dept. of Agricultural Economics and Agribusiness, Accra, Ghana, e-mail: yosei-asare@ug.edu.gh

Sustainable innovations in food production: Evaluating the environmental and socio-economic impact of dry tilapia fish

MARIAM ABDULKAREEM, MILA SELL

Natural Resources Institute Finland, Bioeconomy and Environment, Finland

Within the framework of the HealthyFoodAfrica project, we have identified and piloted innovative approaches aimed at promoting sustainable and nutritious food production, encompassing food processing, safety, packaging, and agri-business models. Among these innovations, Koobi (dry tilapia fish) in oil is particularly promising. In this study, we focus on assessing its sustainability profile and exploring opportunities to promote its consumption within the context of a healthy and sustainable diet. Our objective is to provide fresh insights into the potential of improving local food security, nutrition, and livelihoods in Ghana and, by extension, across Africa. Using the life cycle assessment framework, we conducted an cradle-to-gate environmental assessment of Koobi in oil with a functional unit of 500g. Additionally, a socio-economic assessment was conducted, using a 5-point reference scale approach to evaluate the positive and negative performance of value-chain actors across various social topics. Our assessment integrated both primary and secondary data sources. Preliminary findings for the environmental assessment reveal that the bottle used for packaging Koobi in oil, produced the most global warming impact, and for the socoio-economic assessments, several key impact categories including "fair salary", "freedom of association and bargaining rights", "corruption", "safe living conditions", and "contribution to economic development", exhibited negative performance concerning workers and local community members stakeholders. Furthermore, our study highlights the complexities of global supply chain, considering certain materials (such as tank) for fish farming are imported. This emphasises the importance of adopting a more inclusive and context-sensitive approach to sustainability assessments, advocating for meaningful stakeholder engagement to address local social challenges effectively. In conclusion, our research not only contributes to the understanding of environmental and socio-economic sustainability in small-scale food production but also emphasises the importance of tailored assessments in diverse contexts. By fostering collaboration with local stakeholders, we can pave the way for more equitable and sustainable development trajectories in sub-Saharan Africa and beyond.

Keywords: Agrifood, environmental life cycle assessment, fish

Contact Address: Mariam Abdulkareem, Natural Resources Institute Finland, Bioeconomy and Environment, Latokartanonkaari 9, FI-00790 Helsinki, Finland, e-mail: mariam.abdulkareem@luke.fi

Photovoice as a research method for exploring nutrition and diet quality at a household level: The case of the Mau Narok-Cheragany complex in Kenya

Ndungu S. Nyokabi¹, Lisette Phelan², Henrietta L. Moore ¹

¹University College London (UCL) and University of Edinburgh Business School, Inst. for Global Prosperity, University College London (UCL), United Kingdom

²Wageningen University & Research, Environmental Economics and Natural Resources (ENR), The Netherlands

Household dietary choices play an important role in health and nutrition quality, particularly for children and other members of the household. Household dietary quality and choice are influenced by access to food, cost, and preparation time among other factors. Although dietary quality is known to influence health outcomes, there is a paucity of studies in Kenya focusing on household nutrition, particularly in smallscale farming households.

This study employed a modified photovoice methodology. A team of citizen scientists working in the Prosperity Co-learning Laboratory programme (PROCOL-Africa) identified 70 households to participate in this study. The inclusion criteria included the possession of a mobile phone and willingness to participate in the research. The recruited households took pictures of their meals including breakfast, lunch, dinner, fruits and snacks and shared that with the research team via WhatsApp. Discussions were held to discuss the pictures taken and drivers of dietary choice. Pictorial data were analysed for frequency of meals consumptions. Thematic analysis was undertaken to analyse the recorded discussions.

The research collected pictures of meals that explain the household's dietary quality. There was an over-representation of carbohydrates and vegetables, and a low representation of proteins and fruits in household diets. Discussions with household members during the photovoice debrief discussions revealed that some foods particularly traditional ones were disappearing. The dietary choice was influenced by concerns about nutrition, age food availability, food preparation time, and income among other factors.

The research approach empowers participants to participate and contribute to the research process. Additionally, it addresses the challenge associated with the recall approach to collecting dietary data. There were challenges associated with the photovoice research approach such as fatigue and the low inclusion of poor households without access to mobile phones and/or internet access.

Keywords: Dietary quality, household nutrition, visual research methods

Contact Address: Ndungu S. Nyokabi, University College London (UCL) and University of Edinburgh Business School, Inst. for Global Prosperity, University College London (UCL), London, United Kingdom, e-mail: ndungukabi@gmail.com

Understanding consumers' and retailers' preferences for nutritious foods in Ethiopia: A discrete choice experiment approach

Rosina Wanyama¹, Kevin Onyango¹, Ermias Tesfaye Teferi², Irmgard Jordan¹, Mark Lundy³, Christine G. Kiria¹

¹The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behavior, Kenya

²The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Ethiopia

³The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behavior, Colombia

Poor diets significantly contribute to the burden of malnutrition in many low- and middle-income countries. Increasing uptake of sustainable nutritious foods, especially in low-income households, requires that more of these foods are supplied to their food environment in a way that will enhance desirability and uptake. This study sought to identify attributes that retailers look for when buying nutritious foods from their suppliers and what consumers look for when buying these foods from the retailers. The results will help in proposing interventions that could be tailored to promote scalable, evidence-based innovations and policies to help to promote delivery of sustainable nutritious foods to consumers. Data was collected using a discrete choice experiment conducted among retailers and consumers of tomatoes, bananas, and lentils in lowincome neighbourhoods of Ethiopia's' capital, Addis Ababa, and rural district and town, Butajira, in May 2024. Choice experiments allow for valuation of products using both price and non-price attributes. For tomatoes the non-price attributes assessed include production technology, ripeness, and flesh content. For bananas, they include ripeness, presence, or absence of dark spots when ripe, and size of the fruit. For lentils, they comprise of colour, presence or absence of impurities, and cooking time. A total of 700 retailers and 700 consumers were interviewed from the markets within Addis Ababa and Butajira. Data is being analysed using a mixed logit regression model to obtain preference for selected attributes, and the willingness to pay. Initial results show that retailers' preference for selected attributes may be influenced by consumers' preference and product shelf life. Given the low purchasing power in low-income households, both retailers and consumers prefer lower prices for these products and the premium placed on their preferred attributes are relatively small. Detailed results are presented in the manuscript. We conclude that increasing consumption of nutritious foods in low-income households would require targeted interventions. Interventions that enhance desirability of products coupled with relatively affordable prices may promote consumption.

Keywords: Choice experiment, developing countries, malnutrition, nutritious foods

Contact Address: Rosina Wanyama, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behavior, Nairobi, Kenya, e-mail: r.wanyama@cgiar.org

Organic farming and commercialisation of fruits and vegetables in Makueni county, Kenya

Irene Induli, Rosina Wanyama, Nicanor Odongo, Tosin Akingbemisilu, Céline Termote

The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

Background: Kenya, like many countries in the world is grappling with the challenges of climate change, biodiversity loss, soil degradation, unsustainable food systems, and the triple burden of malnutrition. To counter these challenges, the Alliance of Bioversity and CIAT collaborates with Feedback to the Future (FttF), and the Diabetes Awareness Trust (DAT) to develop an alternative healthy, inclusive, and regenerative food system. This initiative aims to bridge the gap between smallholder producers and vulnerable urban consumers by promoting regenerative agriculture among farmers through training and the sensitisation of vulnerable urban consumers on the consumption of safe, organic foods.

A diagnostic survey was conducted in November 2023, to comprehensively assess farming practices, existing markets, and market integration. From a pool of farmers trained by FttF, 172 were randomly selected for participation. Data collection employed a structured questionnaire covering socio- economic and demographic characteristics, production and marketing practices, storage, food safety measures, labour practices, and value chain governance.

The results show that 90% of respondents were aware of organic farming practices, with 96% of them practicing at the time of the survey. Notably, among those practicing, 88% and 65% engaged in fruit and vegetable farming respectively. Fruit production is relatively more commercialised, with 59.5% of farmers selling their produce compared to 36.2% of vegetable farmers. The most preferred vegetables cultivated are kale, spinach, cowpea, amaranth, and African nightshade, whereas mango, avocado, pawpaw, banana, and orange are the preferred fruit species. Only 8% of fruit farmers cite readily available markets as the reason for their production decisions, while none of the vegetable farmers considered this. Consumption preference by family members is the primary reason behind fruits and vegetables produced as indicated by 19% and 17% of respondents respectively.

While awareness and implementation of organic farming practices among fruit and vegetable farmers in Makueni is widespread, commercialisation of such products, particularly vegetables is still lagging. It is imperative to understand the functioning of existing market networks and collaborate to establish linkages that empower rural smallholders to supply safe, nutritious, fruits and vegetables to vulnerable urban consumers at affordable prices.

Keywords: Commercialisation, food systems, fruits, market linkages, organic farming, smallholder farmers, vegetables, vulnerable consumers

Contact Address: Irene Induli, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, 00200 Nairobi, Kenya, e-mail: i.induli@cgiar.org

A spatially explicit framework for biodiversity intactness reporting in Africa

TOBIAS LANDMANN, FAITH ASHIONO, VINCENT MAGOMERE, HENRI E. Z. TONNANG International Centre of Insect Physiology and Ecology (icipe), Kenya

Here we pioneer the use of multi-sensor earth observation (EO) data and insect *in situ* data collated from various "big data" data platforms (iNaturalists, GBIF, and GenBank.gov) to develop a framework that measures spatially explicit biodiversity intactness patterns over Africa. The used insect taxa are known to be sensitive to ecological changes due to unsustainable farming practices, urbanisation and/or logging. Insect diversity patterns have proven to be useful indicators of overall biodiversity intactness, at various spatial scales.

The UN Convention on Biodiversity Diversity (CBD) and its technical working group for the post-2020 framework has called for unbiased (i.e., accurate), measurable and scalable frameworks and indicators for biodiversity. These should ideally also consider drivers of biodiversity loss, be used to estimate planetary boundaries, and assess the ability of ecosystems to deliver ecosystem services (such as pollination services through insects). The UN Kunming-Montreal Global Biodiversity Framework, likewise, emphasis the need to connect biodiversity loss with ecosystem services and specifically focuses on the integrity of agro-ecological landscapes.

Within the framework, biodiversity intactness was estimated using the ratio between the actual (or currently observed) (o) and the historic or potential (p) estimated insect-based (bio)diversity. Spectral features from 10–20 m Sentinel-2 satellite data, 1-km WorldClim climate variables, 25-m tree heights from the Global Ecosystem Dynamics Investigation sensor, and 1-km human footprint data were used as predictors. The observed patterns (o) were error adjusted using the actual presence of insect taxa, from the big data collections. The pixel-based intactness predictions could be aggregated to individual countries, and conservation priority corridors. Across Africa, high biodiversity intactness could be measured in natural tropical forests, "sky island" mountain areas, islands in Lake Victoria, and arid countries (e.g. Namibia). The framework is adaptable to specific locally threatened species and shows stability over various climate zones, while it can be effectively and spatially aggregated.

Keywords: Africa, big data, biodiversity monitoring, UN convention on biodiversity diversity

Contact Address: Tobias Landmann, International Centre of Insect Physiology and Ecology (icipe), Icipe str. 1, 00100 Nairobi, Kenya, e-mail: tlandmann@icipe.org

Navigating complexity: A framework for updating and monitoring forecasts of nutrition interventions in evolving food environments

Kristen E Bryk¹, Thi Thu Giang Luu², Simone Kathrin Kriesemer², Marinka van der Hoeven¹, Cory Whitney²

¹Vrije Universiteit Amsterdam, Fac. of Science, The Netherlands

²University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany

Malnutrition in all its forms, including undernutrition, micronutrient deficiencies and overnutrition, is a leading cause of disease and death around the world. Economic growth and urbanisation in Vietnam have led to changes in food environments and subsequent changes in dietary patterns and types of malnutrition present, especially in cities. Models that forecast the effectiveness of nutrition interventions offer a holistic approach to addressing nutrition issues in the context of uncertainty and complexity. Theories of change and impact pathways are operationalized to support clarifying relationships between important factors related to decisions, accounting for the system complexity of food environments. Uncertainty and variability within these complex systems require monitoring to gather information, refine ex-ante analyses and update models. In this study, we formulate a protocol for this continuous data collection and model adaptation for nutrition interventions. We use real-world observations of pilot interventions to food environments and a qualitative adaptation of expert knowledge elicitation techniques to narrow our knowledge gap on important variables with high values of information and enhance the robustness of models for forecasting nutrition outcomes. The result is a monitoring framework to guide the systematic evaluation of intervention implementation and continuous model adaptation. We showcase this method for intervention monitoring within the context of the Nutrition Intervention Forecasting and Monitoring (NIFAM) project in our work with school garden interventions across private and public schools in Hanoi. Our approach encourages skepticism in extrapolating intervention outcomes, emphasising the need for tailored adaptations to suit diverse educational settings. Through a focus on learning from actual interventions, our work contributes to developing adaptable models, specifically fit for the complexity of food environments. Our monitoring framework can be widely applied for adaptive management, ensuring the effectiveness of interventions within the broader scope of sustainable food environment initiatives to combat malnutrition.

Keywords: Adaptable models, expert knowledge elicitation, impact pathways, monitoring framework, theories of change

Contact Address: Kristen E Bryk, Vrije Universiteit Amsterdam, Fac. of Science, Amsterdam, The Netherlands, e-mail: kbryk96@gmail.com

Consumer preferences and willingness to pay for certified dried fruits and nuts in Central Asia

Emil Begimkulov, Dietrich Darr

Rhine-Waal University of Applied Sciences, Fac. of Life Sciences, Germany

Dried fruit and nuts play an essential role in the food security and incomes of rural populations of Central Asia (CA). These products partially come from agroforestry (AF) systems, which are viewed to be more sustainable than intensively managed fruit orchards, or nuts collected from the region's dwindling natural forests, given the significant environmental impact of these production systems. Yet, the expansion of AF systems in the region faces limitations such as a lack of knowledge, underdeveloped value addition through processing, absence of environmental and social standards (ESS), and markets that do not adequately differentiate products based on their origin, quality and environmental impact. While Western consumers already demonstrate a growing awareness and consciousness regarding health, environmental, and social impacts of their food consumption choices, it is less clear whether consumers in CA share similar views. Hence, considering the high cost of introducing ESS, small and medium food processing enterprises (SMEs) of CA are unsure about the potential strategic advantage they may obtain from implementing such voluntary standards. In contrast to the substantial research on consumer preferences for fresh fruits and vegetable products, the knowledge in the field of dried fruits and nuts collected from wild forests and AF systems is relatively limited. At the same time, the emphasis on global markets often overshadows the importance of rural and local markets and the trade of certified dried fruits and nuts in developing countries. This study addresses these gaps by a) developing a conceptual framework for consumer preferences and willingness to pay (WTP) for certified food and b) conducting a survey of 300 households and 100 shop buyers in Kyrgyzstan. By employing Discrete Choice Experiments developed via Bayesian D-efficient design, the study examines consumer WTP for certified dried fruits and nuts across multiple dimensions, including food safety, environmental impact, social aspects, place of origin, and price-making it distinct from other studies focusing on fewer dimensions. The findings of this study offer valuable scientific and practical implications for food processing SMEs in CA, guiding their strategies and decisions in a rapidly evolving market landscape.

Keywords: Agroforestry, Central Asia, discrete choice experiments, forests

Contact Address: Emil Begimkulov, Rhine-Waal University of Applied Sciences, Fac. of Life Sciences, Marie-Curie-Str. 1, 47533 Kleve, Germany, e-mail: emil.begimkulov@hochschule-rhein-waal.de

Diversity and economic potential of home gardens in different agro-ecological zones of Lebanon

Abed Al Kareem Yehya¹, Martin Wiehle², Hadi Jaafar³, Thanh Thi Nguyen¹, Andreas Buerkert¹

¹University of Kassel, Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics (OPATS), Germany

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

³American University of Beirut, Dept. of Agriculture, Lebanon

Studies on species distribution across space and time and their underlying drivers has only recently become an important topic in biodiversity research. Understanding these dynamics is fundamental for strategic decision-making and thus relevant in the context of rural-urban transformations. This study investigates the spatial distribution and diversity of tree species within home gardens in three agroecological zones of Lebanon, encompassing six villages. The primary objective of the research is to comprehensively document home gardens and tree species within the study area, with a focus on understanding their diversity levels, the determining factors, and change patterns of land cover. The study applies mixed methods. Using interview data of 20 key informants and 160 semi-structured household questionnaires, we investigated the socioeconomic status of households and the availability of 15 main woody species within their home gardens such as olives, fruit species, and oak varieties. Diversity of home gardens was assessed using the species richness classification and the Simpson Index analysed by Chi-squared tests. We employed a geographically weighted regression (GWR) model using Geographical Information System (GIS) to assess spatial non-stationarity and the relationships between different factors. Relationships such as altitude, slopes, precipitation, land tenure, land use policy, water availability and distance to markets were assessed using GWR regression coefficients. Also, we have mapped of changes in land cover from 1969 to 2023 over time using high resolution classical CORONA (black and white) versus today's Sentinel-2 images. The survey enumerated a total of 13,005 trees across the sampled home gardens. Chi-squared tests of independence reveal a statistically significant associations between species richness and household income and education level with smallholder production, as well as an increased distance from the nearest market. Diversity of trees had a positive spatial autocorrelation and different driving factors in different zones had complex influences on the spatial distribution of trees. Land cover change (with level of accuracy \geq 78 %), demonstrated the relative change in the abundance of trees over time, particularly olives. The data also indicate that tree diversity is vital for stability and sustainability in food security, offering crucial environmental services and maintaining biodiversity.

Keywords: Geographically weighted regression model, spatial distribution, tree species

Contact Address: Abed Al Kareem Yehya, University of Kassel, Organic Plant Production and Agroecosystems Research in the Tropics and Subtropics (OPATS), 37213 Witzenhausen, Germany, e-mail: uk100501@uni-kassel.de

Empowerment as an effect of participation in participatory guarantee systems (PGS): A case study in Argentina

JANNA PFISTER, CHRISTIAN R. VOGL, SONJA KAUFMANN, NIKOLAUS HRUSCHKA BOKU University, Dept. of Sustainable Agricultural Systems, Germany

Participatory Guarantee Systems (PGS) can provide local solutions to promote sustainable and equitable agri-food systems. They enable direct relationships between different actors in the food system, strengthen local markets for organic products, and encourage the active participation of different stakeholders in decision-making processes that affect and guarantee the quality of locally produced and consumed food. The active participation of members is crucial to the effectiveness of PGS and brings many benefits. One of these benefits is empowerment, which is often emphasised but lacks a comprehensive, theoretically grounded understanding. The aim of this study was to gain a better understanding of the empowerment ('power to', 'power with' and 'power within') of producers through their participation in PGS. An exploratory case study involving three PGS initiatives in Argentina was conducted in 2023, using a survey of 21 producers and semi-structured interviews with key informants to address the research objective, based on qualitative content analysis. The results indicate that PGS can promote empowerment processes among producers by enabling positive changes in the dimensions of 'power to' (increased knowledge and economic independence, improved access to markets and machinery through cooperation), 'power with' (increased social network and cohesion) and 'power within' (increased selfconfidence and appreciation). These empowerment processes appear to result from the interplay of collective and individual facets of empowerment, spanning social, economic and political dimensions. Institutional and political support for PGS initiatives seem to play an important role in facilitating the empowerment process of its members. Further research to validate and complement these findings is needed to build a comprehensive understanding of participation in PGS and its impact on the lives of participating producers, to inform both existing and new initiatives.

Keywords: organic certification, certification, empowerment, local food systems, participation, participatory guarantee systems, PGS

Contact Address: Janna Pfister, BOKU University, Dept. of Sustainable Agricultural Systems current address: DITSL, Steinstrasse 19, 37213 Witzenhausen, Germany, e-mail: j.pfister@ditsl.org

Understanding the micro-nutrient chain in northern Ghana

Chike Madueke 1 , Amisu Mohammed 2 , Mouinou Igue 3 , Vincent Avornyo 2 , Ludger Herrmann 1

¹University of Hohenheim, Soil Chemistry and Pedology, Germany ²University for Development Studies, Dept. of Soil Science, Ghana ³Inst. National de Recherche Agricole du Bénin (INRAB), Benin

In 2021, it was reported that up to 70% of the population of sub-Saharan Africa suffer from the impacts of food insecurity and hunger. This is made even more acute by hidden hunger that is mainly caused by micro-nutrient deficiency, cannot be felt, with symptoms – such as fatigue, inappetence, skin diseases, Immunodeficiency, etc. - not easy to decipher. The resultant mental impairment, low productivity, increased morbidity/mortality, especially among children less than 5 years old, would usually have occurred before the need for corrective measures is even noted. The effective nutrients, including copper, iron, manganese, molybdenum and zinc, are largely soilborne. If these soil micro-nutrients were available in adequate amounts, food and fodder plants could absorb them, leading to adequate human uptake for healthy growth and survival. Consequently, a good knowledge of the spatial distribution of these micronutrients would enable site-specific soil management and fertilisation for improved human, animal, and plant nutrition. Unfortunately, data on soil micro-nutrients is grossly inadequate in sub-Saharan Africa. Therefore, the major objective of this study is to develop a methodology for easy/rapid mapping of soil micro-nutrient distribution. For this case study, about 100 soil samples were taken along a 290 km road transect covering different geological/petrographical areas in Northern Ghana. The samples were characterised with respect to mineral (X-ray diffraction), geochemical (X-ray fluorescence) and plant available micro-nutrients (DTPA-extraction) composition. Co-variables like texture, soil organic matter and pH are under investigation. Preliminary data for the plant available fraction show that iron $(15-700 \text{ mg kg}^{-1})$ and manganese $(8-625 \text{ mg kg}^{-1})$ are available in optimum to very high ranges. In contrast, copper content was predominantly very low ($< 0.30 \text{ mg kg}^{-1}$) to low (0.30–0.75 mg kg^{-1}), while zinc and molybdenum were generally deficient, i.e. below 5 and 0.05 mg kg⁻¹ respectively. Soil fertility management programmes should consequently be targeted at improving the nutrient status of copper, zinc and molybdenum in the investigated area. Next steps are i.) the development of an extrapolation algorithm based on proximal/remote sensing gamma spectrometry data, and, ii. the determination of the transfer rate of soil micro-nutrients into food and fodder plants.

Keywords: Gamma spectrometry, hidden hunger, proximal and remote sensing, soil mapping

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

Forecasting adults' inclination towards adopting healthy dietary habits: A case study from rural and urban Tanzania

Masoud Yazdanpanah¹, Niloofar Khalili², Katharina Löhr², Constance Rybak³

¹Agricultural Sciences and Natural Resources University of Khuzestan, Iran

²Leibniz Centre for Agricultural Landscape Research (ZALF), Germany

³Humboldt-Universität zu Berlin, Thaer-Institute - Div. Urban Plant Ecophysiology, Germany

The "triple burden of malnutrition", 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 in some developing countries such as Tanzania. Improving dietary intake habits is one essential objective in public health initiatives. Comprehending human perception and behaviour concerning these healthy dietary habits is crucial for designing appropriate policies aimed at fostering a healthier society, particularly in developing countries like Tanzania. The present study endeavours to forecast adults' inclination toward adopting healthy dietary habits by utilising the Health Belief Model, supplemented by the additive influences of health identity and knowledge, rooted in the 'Identity Theory and the Knowledge, Attitude, and Practice' (KAP) model. For the study, 567 adults were from an urban and rural cohort in Tanzania. Survey-based data collection was conducted in 2023 in two distinct places of residence, namely Ilala/Dar es Salaam (urban) and Pwani region (rural) Tanzania, to allow for a comparative analysis of the rural-urban divide., Structural equation modelling revealed that the extended Health Belief Model (HBM) elucidated 48% of the variability in adults' inclination toward healthy eating choices. Subsequently, the differences/similarities in place of residents and variables of HBM were investigated using the t-test. Results revealed that urban and rural residents significantly differ from each other regarding their knowledge, attitude, health value, cue to action, and intention toward healthy eating choices. The mean score of urban residents was higher than that of rural residents in all these variables. These findings hold the potential to guide educators and policymakers in developing persuasive communications that effectively influence individuals' intentions to adopt healthier eating habits.

Keywords: Dietary intake habits, food, HBM, perception and behaviour

Contact Address: Niloofar Khalili, Leibniz Centre for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, 15374 Muncheberg, Germany, e-mail: niloofar.khalili@zalf.de

A photovoice study on the influence of the built food environment on individuals' food choices

Lucy Apiyo Adundo $^{1,2},$ Ramona Teuber 2, Tosin Akingbemisilu 3, Joost Dessein 1

¹Ghent University, Dept. of Agricultural Economics, Belgium

²Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Germany

³The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

Food environment is described as the interface where individuals interact within the wider food system to acquire and consume their foods. It encompasses availability, convenience, affordability, quality and promotion, and sustainability of foods and beverages in built, wild and cultivated spaces, which are influenced by socio-cultural, political environments and ecosystems in which they are embedded. This insinuates that the food environment plays a vital role in ensuring (un)healthy diets for individuals. The purpose of this study was to determine the influence of the built food environment (FE) on individual food choices and socio-cultural food practices in Nairobi, Kenya. We used a mixed-method approach to better understand the drivers of food choices. We assessed the food environment using vendor mapping and a photovoice approach to assess individuals' dietary choices. We conducted in-depth interviews with twenty-four individuals in three income regions: Kilimani/Kileleshwa, Viwandani and Kasarani. 3458 food vendors and outlets were mapped within these three settlements. We estimated the distribution of food vendors within each settlement in correspondence to where consumers buy from. From the participants' photos, we found that how individuals interacted with their food environment was influenced by their income, convenience, time, health and family food preferences. Physical food access, availability and safety were other influencing factors. Our research findings suggest transformative solutions such as promotion of healthy diets, and affordable food prices for staples, fruits and vegetables among all population backgrounds. Also, interventions should increase physical access to culturally appropriate, nutritious and healthy diets, to promote better nutrition practices.

Keywords: Dietary choices, food environment, photovoice, socio-cultural food practices

Contact Address: Lucy Apiyo Adundo, Ghent University, Dept. of Agricultural Economics, Coupure links 653, 9000 Ghent, Belgium, e-mail: lucyapiyo.adundo@ugent.be

Influence of front-of-pack design of child food products on the choice behaviour of Beninese customers

IRIS SCHRÖTER¹, INA CRAMER¹, GEORGES DJOHY², MARCUS MERGENTHALER¹ ¹South Westphalia University of Applied Science, Agricultural Economics, Germany ²University of Parakou, National School of Statistics, Planning and Demography (ENSPD), Benin

Front-of-pack (FOP) design elements communicate directly to customers and are therefore considered a key factor in the point-of-purchase decision. This importance of FOP design prompted a series of conventional and participatory studies aimed at supporting women's groups in Nikki and Banikoara, northern Benin, to develop an appealing FOP design for their artisanal child food products. Based on this groundwork, a local designer created drafts of the FOP design for two products per location: porridge and stew in Banikoara; porridge and sweets in Nikki. Following an evaluation and selection procedure, the colour design and the position of the groups' logo remained under discussion. To clarify this issue, a field experiment was conducted with 64 potential child food customers in Banikoara and 99 in Nikki: The products were packaged in 500 g portions and labelled in four design variants, varying the position of the logo (bottom/top) and the background colour (pale/intense). Simulating an open market situation, participants were asked to select one pack of each of the two products offered at each location, to rate the attractiveness of the design and to provide an estimate of the realistic product price and the maximum price they would be prepared to pay. Each individual was financially compensated for participating in the study.

The results indicate that the design features analysed had no influence on the participants' choice for the porridge products. An intense background colour was preferred for both the stew and the sweets, with the latter also demonstrating a preference for the logo to be placed at the bottom (p < 0.05). The packaging design was generally considered attractive. However, it was rated higher in Nikki than in Banikoara (p < 0.05), indicating that there is still room for improvement. The estimated realistic prices for all products were found to be similar. However, approximately 20% of participants in Nikki stated a maximum price below the realistic price, indicating that they do not perceive the product to be affordable for themselves.

The findings may be used to inform the refinement of the FOP design and the marketing strategy of the women's groups.

Keywords: Child food affordability, logo position, packaging attractiveness

Contact Address: Iris Schröter, South Westphalia University of Applied Science, Agricultural Economics, Lübecker Ring 2, Soest, Germany, e-mail: schroeter.iris@fh-swf.de

Evaluation of build food environments mapping approaches for policy decision making: Perspective from Kenya, Benin, Uganda and Ivory Coast

TOSIN AKINGBEMISILU, IRMGARD JORDAN, CÉLINE TERMOTE The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

Mapping the build food environment is important for understanding availability, accessibility, and its impact on public health for policy and intervention planning. The Alliance of Bioversity and CIAT conducted food environment mapping, using three different mapping approaches – administrative and community approach in Kenya, and centered approach in Benin, Uganda and Ivory Coast. This study critically evaluates these approaches to determine their efficacy and limitations, while focusing on which method best integrates with geographical and public health data for enhanced policy decision-making.

The administrative approach employs predefined geographical national administrative boundaries like districts. The community approach focuses on smaller, specifically selected community areas within a larger region, attempting to capture localised food environment details. In contrast, the centered approach identifies a central point, e.g. school, hospital or shopping centre and encompasses a designated radius around it (e.g. 1 km).

The administrative approach provides a robust dataset that aligns well with national data systems, that easily synchronises with existing demographic and health data, ideal for comprehensive spatial integration and analysis, making it highly suitable for policymaking. However, in large administrative areas, it can be time intensive. The community approach, although rich in local insights, lacks accessible geographical and population data, necessitating local engagements for data acquisition, which often leads to estimation bias. The centered approach, the least costly, offers rapid data collection but may misrepresent the actual distribution of food vendors within the administrative area, affecting the reliability of derived indicators like vendor density per population or per square kilometer, that potentially leads to spatial estimation bias. Each method exhibits inherent trade-offs between accuracy, cost, and operational feasibility.

The study reveals that while each approach has its merits, the administrative method provides the most reliable framework for integrating spatial and health data, facilitating accurate policy analysis and decision-making. Future efforts should aim to leverage the strengths of each method to utilise the approach or develop a hybrid approach that maximises accuracy and efficiency, particularly in linking food environment characteristics with health outcomes to better inform public health strategies.

Keywords: Approach, framework, health outcomes, policy, retail, spatial

Contact Address: Tosin Akingbemisilu, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, ICIPE Duduville Campus, P.O. Box 823-00621 Nairobi, Kenya, e-mail: T.Akingbemisilu@cgiar.org

Challenges in the use of a solar ice production and drying systems in Kenya

 $Alexander \ Morgenstern^1, \ Matthias \ Fischer^2, \ Albert \ Esper^2$

¹*Fraunhofer-Institute for Solar Energy Systems ISE, Heating and Cooling Technologies, Germany*

²Innotech Ingenieursgesellschaft mbH, Germany

In February 2023 the SolCoolDry - solar ice production and drying system has been officially inaugurated and handed over to the Beach Management Unit (BMU) Mwazaro, at the south coast of Kenya. The cooperation project of partners from Germany and Kenya and the realised system is financed by funding from the German Ministry for Food and Agriculture. More than one year of operation accompanied by tests and analyses concerning hygienic and quality aspects reveals the main advantages by the use by the local community but also shows the still challenges between interest and real use.

The flake ice machine in Mwazaro is currently the only ice machine in the wider area that still produces high-quality ice. Despite the high demand for flake by the fishermen and fish traders in principle the ice sells never reached the production capacity. Minor technical problems that arose during operation were resolved remotely by the BMU's technical staff. However, it has not yet been possible to create reserves for major repairs.

The solar tunnel dryers are under regular use, but also far below it's capacity. This is partly due to the lack of raw materials and partly because potential users are not yet sufficiently convinced of the benefits of the systems. Traditional drying of Kimarawali (small sardines) on the ground, directly on the landing sites, is still the preferred procedure. Due to the current economic conditions in Kenya, hardly any added value can be achieved on the market for a better quality of dry products, so that the additional work involved has not yet paid off. This is particularly true for the fishermen of Kimarawali. In addition, the fishermen still only dry products that cannot be sold as fresh fish on the market. In opposite, the dryers are more and more used by the local farmers depending on the seasonal harvest.

As part of the EU-funded INNOECOFOOD project, the above-mentioned solutions for solar ice production and drying are being integrated directly into special fish farms with RAS technology. A regular and efficient use of the technologies is expected under these specific boundary conditions.

Keywords: Fishermen, flake ice prodution, food preservation, solar drying

Contact Address: Alexander Morgenstern, Fraunhofer-Institute for Solar Energy Systems ISE, Heating and Cooling Technologies, Heidenhofstraße 2, 79110 Freiburg, Germany, e-mail: alexander.morgenstern@ise.fraunhofer.de

Does diversification of farming reinforce diversity of diet?

Ermias Tesfaye Teferi¹, Carlo Fada¹, Enrico PE²

¹The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Ethiopia

²Scuola Superiore Sant'Anna, Inst. of Life Sciences, Italy

The purpose of this study is to investigate the relationship between the diversity of foods consumed by households and the variety of agricultural products produced, as well as on household income and market involvement. Data were collected from 303 farm homes in the Meket area, which is in the northeastern part of Ethiopia. Through the process of registering the various food crops and livestock species that the household has grown and reared over the course of the previous year, production diversity was successfully documented. For the purpose of determining the impact that crop production has on dietary diversity, the Simpson diversity index and crop species count were computed for sample households and then incorporated into the Poisson model in a different manner. In a similar vein, the number of different types of livestock that a household possessed was used to determine the variety of the animals. According to the findings, roughly 29 percent of the families that were included in the sample produced and consumed more than six different types of crops during the most recent production season and the recall period, respectively. The findings of the econometric calculation showed that there is a positive and substantial relationship between agricultural production and dietary diversity. This means that an increase of one unit in crop production diversity leads in a 25 percent rise in dietary diversity. In a similar vein, the revenue from eucalyptus plantations, gender, the distance to market, and the size of the family all have a positive and substantial impact on the dietary habits of individuals. According to the findings of the research, diversification seems to have significant consequences in terms of diversity in diets and, therefore, the health of rural families. This is in addition to the benefit of risk aversion, which is the most often cited advantage of diversification. When the findings of the research are taken into consideration, significant implications are highlighted.

Keywords: Dietary diversity, Ethiopia, production diversity, Simpson index

Contact Address: Ermias Tesfaye Teferi, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Gurd Shola, Addis Ababa, Ethiopia, e-mail: e.tesfaye@cgiar.org

Effect of packaging materials, storage methods, and duration on functional qualities of red-hot pepper powder

Obse Fikiru¹, Hana Zinabu Dulo¹, Sirawdink Fikreyesus Forsido¹, Yetenayet Tola¹, Tessema Astatkie²

¹Jimma University, Dept. of Post-Harvest Management, Ethiopia ²Dalhousie University, Fac. of Agriculture, Canada

Hot red peppers (Capsicum annuum L.) pungency, aroma, colour, and nutritional and medicinal qualities are highly prized. The stability of the functional qualities of red pepper is affected by variety, growing condition, maturity at harvest, drying technique, improper packaging, and storage duration and conditions. The current study aimed at selecting good packaging materials, storage methods, and durations that preserve the highest functional qualities at the end of the storage study. Low-density polyethylene(LDPE), highdensity polyethylene (HDPE), aluminum poach (AlP), and BLDPE (blackcoloured low-density polyethylene) bags were heat-sealed. The samples were stored at ambient conditions for ten months. Data on moisture content (MC), total carotenoids (TCC), pungency index (PI), oleoresin content (OLEO), and total antioxidant capacities (TAOC) were collected at two-month interval. A significant (p < 0.001) interaction effect of packaging material and storage duration was observed in all studied response variables except for MC and pungency index. Storing red hot pepper powder under refrigerated and at room temperature for up to six months in all packaging materials is possible. However, aluminum foil is recommended for storage beyond six months under both storage temperatures, though HDPE can take the second rank. Black-coloured LDPE showed greater retention capacity, though the result was not significant compared to transparent LDPE bags. Compared to room temperature storage, refrigerated storage is preferable for better retention of functional quality of red hot pepper powder. Samples packed in aluminum pouches maintained high functional qualities at the end of the storage period which could be due to the lower permeability of aluminum pouches to water vapour and oxygen under both room and refrigerated storage methods. The findings suggest further studies on the effect of these packaging materials and storage duration on other nutritional variables and the product's safety.

Keywords: Oleoresin, pungency, red hot pepper, total carotenoids

Contact Address: Obse Fikiru, Jimma University, Dept. of Post-Harvest Management, Jimma, Ethiopia, e-mail: sonankena@gmail.com

Local innovation support facility (LISF) as a catalyst for farmer creativity in developing innovative solutions for food and nutrition security in northern Benin

Nicole Sarah¹, Georges Djohy², Léonard Adje³

¹Better Life NGO & Prolinnova-Benin, Borgou, Benin

²University of Parakou, National School of Statistics, Planning and Demography (ENSPD), Benin

³Espérance-Vie NGO & Prolinnova-Benin, Benin

Local Innovation Support Facility (LISF) is an alternative assistance mechanism based on small funds providing access to finance for low-resource innovative farmers to promote and improve their local innovations. With a view to expanding the promotion of local innovation for food security and healthy nutrition to build resilience, Prolinnova-Benin - a multi-stakeholder country platform for promoting local innovation in agroecology and natural resource management in Benin – set up LISFs in two districts in northern Benin, namely Bembéréké and Tchaourou. This article analyses the extent to which the LISF has been taken up by grassroots actors and its impact on food and nutrition security. A qualitative approach was used to trace the process of setting up the LISF from the launch of the call for applications to the granting of funds. A total of 17 applications were received from farmers/groups, presenting in video form in local languages the difficulties encountered in their activities, the local innovations developed as solutions, the research ideas pursued, the material needs and the actual use of the funds. Participant observations were made during the review of applications by local multi-stakeholder committees based on criteria locally set. Open-ended interviews were conducted as part of follow-up visits with seven (07) innovators, including five (05) women selected as LISF beneficiaries, in order to ascertain how they used the funds allocated and what the initial effects were on their livelihoods. Preliminary results showed that the local multi-stakeholder partnership created around the LISF made it possible to target local innovations of great importance for food and nutrition security: soya yoghurt, flavoured shea butter, improved cashew apple juice, bonebased pesticide, spicy groundnut fritters and basil leaf-based chicks adoption. The fair assessment of requests and the transparent communication on funds allocation strengthened the confidence of innovative farmers and boosted their self-confidence through recognition of their creativity. In addition, improving farmers' investment capacity through LISF had a positive effect on their activities, by increasing productivity and income. These results are relevant to actions and policies aimed at mainstreaming local innovation and participatory innovation development approaches into agricultural research and development.

Keywords: Benin, farmer creativity, food and nutrition security, local innovation, local innovation support facility

Contact Address: Georges Djohy, University of Parakou, National School of Statistics, Planning and Demography (ENSPD), 03 BP 303, Parakou, Benin, e-mail: gdjohy@gmail.com

Preserving resources, securing livelihoods: Reducing food loss and waste for sustainable development in Ghana

Dorcas Twumwaa Gyan 1 , Faustina Appia
a ${\rm Gyan}^2, {\rm Esi} \, {\rm Dadzie}^1$

¹Southern University and A&M College, Dept. of Urban Forestry, Environment and Natural Resources, United States

²University of Cape Coast, Dept. of Business and Social Science Education, Ghana

Food loss and waste represent significant challenges to sustainable development worldwide, impacting both food security and environmental sustainability. In Ghana, a country with a rich agricultural heritage and diverse food systems, these challenges are particularly pronounced in most rural farming communities. Despite significant progress in agricultural production and food distribution, a substantial portion of the food produced in the country is lost or wasted each year, increasing poverty among rural farmers. This problem not only undermines efforts to improve food security and nutrition but also represents a significant economic loss for farmers and other stakeholders along the supply chain. Moreover, food loss and waste contribute to environmental degradation, including greenhouse gas emissions and resource depletion. Addressing this issue requires a comprehensive understanding of the factors contributing to food loss and waste in Ghana and developing effective strategies and interventions to mitigate it. This study aims to systematically review the scale and impact of food loss and waste on food security, the livelihood of farmers, and environmental sustainability in Ghana. This study will delve into innovative strategies and community-led efforts to minimise food loss and waste throughout the food supply chain. These include initiatives such as improved postharvest handling practices, local food processing innovations, and community-based food recovery programs. These efforts have contributed to improved livelihoods, increased resilience, and enhanced social cohesion within communities by preserving valuable resources, reducing economic losses, and enhancing food security. Through collaborative partnerships, policy support, and grassroots initiatives, Ghana has the opportunity to lead the way towards a more resilient and prosperous future for its communities.

Keywords: Food loss, food waste, resources, sustainable livelihood

Contact Address: Dorcas Twumwaa Gyan, Southern University and A&M College, Dept. of Urban Forestry, Environment and Natural Resources, 1443 Brightside Drive, 70820 Baton Rouge, United States, e-mail: twumwaamaabena@gmail.com

PlaSa Colombia: A data-based systemic approach for transforming food systems

JOHANA MARCELA CASTILLO RIVERA, SARA RANKIN, CARLOS EDUARDO GONZALEZ The Alliance of Bioversity International & CIAT, Colombia

Food systems in Colombia, like in many countries around the world, face multiple challenges, such as climate risk, production inefficiencies, obesity, hunger, foreign dependency, food loss, and waste, food insecurity, climate shocks, inefficiencies in supply logistics, and overall, a lack of understanding of their interconnections, interdependencies, and trade-offs. Paradoxically, Colombia has abundant data on some of the main elements of its food systems (production, supply, marketing, transportation, nutritional status, among others); however, these data are often not easily accessible, not integrated, nor analysed together, limiting their usefulness in decision-making processes, planning, and the design of programmes and strategies. This document explores how a systemic approach can transform decision-making using data tools such as the food systems platform PlaSA Colombia, created by the Alliance of Bioversity and CIAT. This platform integrates and simplifies scattered data, facilitating public access and understanding and promoting informed decision-making. PlaSA aims to provoke debates about the type of food system desired and to influence public policies with information structured through multidimensional data, facilitating the construction of narratives, based on secondary data from public sources, that simplify complex data into clear images. Information gaps have motivated the scientific and academic community, now united in a Community of Practice on Food Systems (first in the country), to mobilise efforts and create collaborative networks to develop joint solutions. Collaborative exercises that have been carried out at the national level through PlaSA Colombia have made it possible to understand the impacts generated by roadblocks on GHG emissions and food supply, the cost of diets, and their affordability for major cities, and the Agro-climatic factors that affect productivity, among others, which are often overlooked in more fragmented approaches. In conclusion, improving collaboration is crucial to influencing decisions and promoting political and sectoral reforms. This study highlights the need for tools like PlaSA Colombia for a detailed and ongoing analysis, inviting regional, national, and local stakeholders to adopt similar approaches to enhance the resilience and sustainability of food systems.

Keywords: Challenges, climate change, collaboration, food security, food system, PlaSA Colombia, sustainability

Contact Address: Johana Marcela Castillo Rivera, The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact, Av 2 hn #54-05, Cali, Colombia, e-mail: j.castillo@cgiar.org
Consumer preferences and willingness to pay for certified high-iron beans among urban households in West Pokot County, Kenya

Donald Kirwa¹, Eric Gido¹, Charles Karani²

¹*Egerton University, Dept. of Agricultural Economics and Agribusiness Management, Kenya*

²Pwani University, School of Agricultural Sciences and Agribusiness, Kenya

Enhancing transparency in the food system through initiatives like product certification is crucial as it provides consumers with essential information to facilitate informed nutritional choices. In the context of common beans, understanding consumer preferences for certified high iron common beans is important to enhance their consumption. To address this, a choice experiment was conducted to determine household decision maker's preferences for certified high iron common beans and the underlying determinants in the urban areas of West Pokot County, Kenya. The data were collected by a multi-stage sampling technique on a sample of 384 household decision makers with the aid of semi-structured questionnaire and choice cards. Data were analysed using JMP 17 and STATA 17 computer software. Mixed logit model results showed household decision makers had a positive preference for certification of high iron common beans by public bodies and mandatory labeling of these beans. However, they had a negative preference for highly processed high iron beans and the certification of high-iron common beans by a private body. Age and education were identified as heterogeneous factors. Relative to the current price of uncertified Nyota beans, a high-iron common bean variety. Household decision makers were willing to pay (Kenya Shillings (KES) 22) and (KES 9) per kilogram for certification by a public body and mandatory labeling of high-iron common beans, respectively. However, they were unwilling to forgo (KES 9) and (KES 18) per kilogram for highly processed beans certified by a private body, respectively. This study therefore recommends mandatory labelling of high-iron beans, a joint private public certification approach, and government-backed certification of high iron common beans. In addition, employing marketing strategies that are tailored to consumers heterogeneous factors and those recognising regional consumer preferences would enhance high iron bean consumption.

Keywords: Certification, choice experiment, consumer preferences, high-iron common beans, urban areas

Contact Address: Donald Kirwa, Egerton University, Dept. of Agricultural Economics and Agribusiness Management, Egerton, Kenya, e-mail: kirwadonald77@gmail.com

Peaberry coffee beans shape influence final cup quality

Eduardo Duque-Dussan¹, Juan Rodrigo Sanz-Uribe¹, Paula Andrea Figueroa-Varela²

¹National Coffee Research Center of Colombia, Colombia ²EAFIT University, School of Applied Sciences and Engineering, Colombia

It was traditionally considered that coffee peaberries were a defect in the coffee production process. There are usually two plano-convex seeds inside the berry; however, a single ellipsoidal seed may form for biological reasons: the peaberry. Due to this mutation, the peaberries were long considered a defect; further, their export was banned in many coffee-producing countries due to their significantly reduced shape and the worldwide demand for supreme beans. However, different sensory evaluations have revealed that the peaberry has a high cup quality. It is hypothesised that the bean shape accounts for these results. The roasting process occurs homogeneously throughout the bean's domain, and its shape makes it easy for it to roll inside the roaster enclosure. Nevertheless, the data shared in the literature regarding this topic are relatively scarce. Therefore, this study aimed to perform a set of image analyses on 3 samples of coffee beans (Coffea arabica L): 120 g of standard grain, 120 g of peaberries and a mixture of 60 g of standard and 60 g of peaberries. The samples were then medium roasted at the same temperature and conditions to better observe the tonality and roast uniformity in 100 randomly selected beans from each sample, from which 50 were cut transversely and 50 longitudinally. Afterwards, a high-resolution picture was taken with a stereoscope, normally located on the flat face. The pictures were processed through image analysis to identify colour mapping, intensity, discontinuities and anomalies in all the grains. The tonality was less variable in both individual and mixed samples of peaberries. Standard berries displayed anomalies in their inner structure generated during the roasting process in both individual and mixed samples. During the roasting process, air chambers formed inside the bean, which resulted in heat accumulation and overroasting, resulting in undesirable flavours and reducing the cup profile and quality.

Keywords: Coffee bean, image analysis, peaberry, roasting

Contact Address: Eduardo Duque-Dussan, National Coffee Research Center of Colombia, km 4 vía Chinchiná-Manizales, Manizales, Colombia, e-mail: eduardo.duque@cafedecolombia.com

Consumers' willingness to pay for certified and hygienically handled smoked catfish in Ibadan North local government area, Oyo State, Nigeria

SIYANBOLA OMITOYIN¹, ADEYINKA ADEDIWURA², TEMITAYO ADEYEMO² ¹University of Ibadan, Aquaculture and Fisheries Management, Nigeria ²University of Ibadan, Dept. of Agricultural Economics, Nigeria

Value addition in agrifood systems is required to enhance livelihood, nutrition, and sustainability outcomes. In Nigeria, aquaculture production has become an important subsector in the agrifood system, with opportunities for meeting the food security and employment needs of many individuals. The process of smoking catfish is a popular value-addition method in Nigeria, however, there are concerns about the health risks due to reported unhygienic handling and contamination. This research investigated how much consumers in Ibadan North Local Government Area, Nigeria, were willing to pay for hygienically handled and certified smoked catfish using a Contingency Valuation method. A multi-stage sampling technique was used to obtain data from 130 respondents through a multistage sampling process. While a significant number (73.85%) were aware of proper hygiene practices for handling and smoking catfish, only 47.69 % were aware of certified smoked catfish being available. The mean willingness to pay was N400 and N905 per pack of 145 grams of certified and hygienically handled smoked catfish, respectively. The Heckman model employed revealed that the purchase frequency; monthly income, education, occupation, and sales point proximity influence consumers' willingness to pay for hygienically handled fish. Determinants of average premium for certification included quality perception and purchase frequency. The study recommends that improving hygiene standards and consumer awareness could significantly increase the market value of smoked catfish; thus, enhancing both livelihood and nutrition outcomes in the country.

Keywords: Certification, hygienically handled, smoked catfish, willingness to pay

Contact Address: Siyanbola Omitoyin, University of Ibadan, Aquaculture and Fisheries Management, Oyo Road, Ibadan, Nigeria, e-mail: sbomitoyin@yahoo.com

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The natural imperative for African aquaculture species and system diversification: Case studies from Ghana

LOISE SARFO¹, EMMANUEL NYAMEKYE¹, EMMANUEL FRIMPONG² ¹Consulting in Aquatic Research and Training for Development (CART4D), Ghana ²Virginia Polytechnic Institute and Sate University, Dept. of Fish and Wildlife Conservation, United States

Aquaculture has been promoted over the last seven decades as a solution for persistent animal protein shortage in Africa. Over the same period, Africa has lagged well behind the world, especially Asia, in the growth of aquaculture. In recent decades, the causes of slow pace of aquaculture development in Africa have been recognised as a combination of emphasis on subsistence, a one-size-fits-all paradigm of development, and a lack of encouragement of local innovation. For example, two species: Nile tilapia (Oreochromis niloticus) and African catfish (Clarias gariepinus) were widely promoted for aquaculture across the continent, with production primarily conducted in earthen ponds, whereas demand for specific fish products varies widely by region, country, ethnic, and social groups. On production systems, it is only a recent increased adoption of cage-based aquaculture that has significantly increased the contribution of aquaculture to national fish production in countries such as Ghana. This study makes the overarching case that 1) there are sustainable aquaculture systems that could be adopted at scale in Africa to increase aquaculture production, and 2) there are many native species that could be developed and cultured to diversify aquaculture systems and make them more resilient to environmental change. Results are presented here of a test of a pilot small-scale aquaponics system involving the production of Africa catfish and tomatoes in a closed nutrient cycle with minimal waste discharge. Six months of production resulted in an output 300 kg of catfish in a 4 cubic metre capacity concrete tank and 25 kg of tomatoes in a 1.5 square metre grow bed all in a 6-month production cycle. Additionally, results will be presented on captive breeding and feeding trials of two species native to Ghana and previously unknown in aquaculture-Coptodon zillii and Coptodon discolour, the latter of which is a species declining in capture fisheries. The success of breeding these species in captivity and raising them on existing tilapia feeds provides opportunities for species diversification. The major challenge facing adoption of recirculating aquaculture systems in Ghana is unreliable and expensive electricity. Development of solar energy technology for aquaculture in Africa is highly recommended.

Keywords: Aquaculture, aquaponics, food security, lesser-known species

Contact Address: Emmanuel Frimpong, Virginia Polytechnic Institute and Sate University, Dept. of Fish and Wildlife Conservation, 310 West Campus dr, 24061 Blacksburg, United States, e-mail: frimp@vt.edu

Effects of improved pond aquaculture techniques on household well-being: A case study from rural Bangladesh

Nusrat Zaitun Hossain 1 , Ulrike Grote 1 , Sourabh Kumar Dubey 2

¹Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Germany

²WorldFish, Bangladesh

Homestead pond aquaculture is considered sustainable in terms of fish availability and choice. Fish, in particular indigenous small fish (ISF), are known to improve food security and provide a source of income, and the poor can purchase small quantities of fish to supplement their diets. However, it is not clear to what extent households benefit from polyculture systems including ISF. One way to promote ISF production is via Improved Pond Management Techniques (IPMTs). This paper sheds light on the adoption of IPMTs in homestead ponds, their costs and returns and their effects on household well-being. Household well-being refers to- 1. income calculated as the net return from homestead pond in USD per hectare; 2. consumption of fish measured in gram per capita per day; and 3. household poverty includes the percentage of households living below 1.90 USD per capita per day.. It uses data obtained from a two round panel survey of 234 households from three sub-districts in Barishal district, situated in Barishal division of Bangladesh in 2014 and 2022. Results reveal that cost and gross return increase in 2022 compared to 2014. The two-stage least-squares logit regressions with instrumental variables show that there is a significant and positive effect of IPMT adoption on household well-being. This is especially true for adopting IPMTs such as sunlight exposure, pre-stock liming, supplementary feeding and fertiliser application together as a package on per capita daily fish consumption and household poverty defined by household living under 1.90 USD per day. However, the net return from homestead pond production does not seem to be significantly correlated with IPMT adoption.

Keywords: Control function approach, homestead pond aquaculture, instrumental variable, two-stage least squares logit regressions, well-being

Contact Address: Nusrat Zaitun Hossain, Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, königsworther platz 1, 30159 hannover, Germany, e-mail: hossain@iuw.uni-hannover.de

Evaluation of faecal indicator bacteria and antimicrobial resistance of *Escherichia coli* isolated from river Njoro, Nakuru county, Kenya

Lorine Auma Omondi, Nzula Kitaka, Anastasia Wairimu Muia Egerton University, Biological Sciences, Kenya

Agriculture, urbanisation and industrial activities are a threat to surface water quality. The wastes generated from these activities are discharged into rivers directly or indirectly consequently altering the physical, chemical and biological quality of rivers. Human settlements and associated land use activities have compromised water quality of River Njoro, Nakuru County, Kenya causing environmental and public health concerns including diseases and antimicrobial resistance of microbial risks to medical drugs. The aim of this study was to investigate the effect of human activities on faecal pollution of River Njoro and to evaluate antimicrobial resistance of Escherichia coli isolated from the river water to a selected group of antibiotics. Antibiotic susceptibility of *E. coli* isolated from the river water samples was tested using Kirby-Bauer disc diffusion assay. The strain E. coli ATCC 25922 was used as antibiotic susceptibility reference standard. Both physico-chemical and bacteriological variables varied significantly among the sampled sites except for total suspended solids (p < 0.05). A significant difference in antimicrobial resistance of E. coli isolated from River Njoro was observed between the sampling sites except for amikacin and amoxicillin (p < 0.05). Antimicrobial susceptibility test revealed that E. coli isolated from water at different sections of the river were resistant to multiple antibiotics. A high resistance prevalence was recorded in streptomycin (95.83%), chloramphenicol (86.11%), ciprofloxacin (86.31%), amoxicillin (85.71%) and tetracycline (82.14%). Multiple antimicrobial resistance index were greater than the threshold of 0.2 in all the sites. Results from this study can be used in predicting potential microbial risks to human health and to provide mitigation measures towards protection of water resources against pollution.

Keywords: Antibiotic resistance, *Clostridium perfringens, Escherichia coli, Intestinal enterococci,* water quality

Contact Address: Lorine Auma Omondi, Egerton University, Biological Sciences, 536, 20115 Nakuru, Kenya, e-mail: lorineauma@gmail.com

Freshwater shrimp farming in captivity in Burkina Faso: Cases of *Macrobrachium dux* and *Macrobrachium* sp

RIMWAODO PIERRE SILGA¹, NADÈGE NABI¹, ADAMA OUEDA² ¹University Joseph KI-ZERBO, Department of Biology and Animal Ecology, Burkina Faso ²University of Ouahigouya, Burkina Faso

In Burkina Faso, shrimp is the second source of aquatic animal protein after fish. Contrary to the fish where we are currently witnessing the development of their farming through fish farming, shrimp farming is still in the embryonic stage and their rearing conditions are not yet mastered. The objective of our study was to assess the survival rates of two captive-reared freshwater shrimp species. To do this, specimens of these species were caught in the Loumbila dam lake in Burkina Faso and survival tests were also conducted at the Laboratory. Each species of shrimp was raised in triplicata in tanks of volume 60 liters filled with water at 3/5. The shrimp were fed a food made from local ingredients. A follow-up of physico-chemical parameters (pH, temperature, electrical conductivity and dissolved solids) was performed. Means of the physico-chemical variables 7,65 – 7,64 – 7,51 (pH), 26,00°C – 25,6°C – 26,18°C (temperature), 556,7 μ S.cm⁻¹ – 545,53 μ S.cm⁻¹ – 406,33 μ S.cm⁻¹ (electrical conductivity) et 277,5 ppm – 272,8 ppm – 203,27 ppm (dissolved matter) have varied slightly and respectively in lots 1; 2 and 3. No significant differences in the variables between the different lots were observed. In terms of captive shrimp breeding trials, analyses of condition factor K and survival rate revealed that Macrobrachium sp is the most suitable species for captive breeding in terms of its size and survival rate (67%) against an 11% survival rate for Macrobrachium dux. Taking into account other variables such as dissolved oxygen, nitrogen and phosphorous compounds and a long-term experiment in semi-natural conditions is essential for a better understanding of the conditions of freshwater shrimp farming.

Keywords: Farming, nutrition, shrimp, West Africa

Contact Address: Rimwaodo Pierre Silga, University Joseph KI-ZERBO, Department of Biology and Animal Ecology, Rn4-Bendogo, 03 BP 7021 Ouagadougou, Burkina Faso, e-mail: pirelrelwender@gmail.com

Role of social networks in exposing smallholder farmers to cage fish farming technologies

JOHN LIVINGSTONE MUTYABA, W. MARGARET NGIGI, OSCAR INGASIA AYUYA Egerton University, Agricultural Economics and Agribusiness Management, Kenya

In sub-Saharan Africa, agricultural sector is greatly affected by access and use of information. Governments and development partners use agricultural extension systems to provide farmers with the necessary information. Extension services are widely regarded as the panacea for agricultural and technological information diffusion among farmers. Nonetheless, despite their importance, Uganda's present extension system of one extension Agent to 1,800 farmers, provides insufficient help to smallholder farmers. As a result, farmer-to-farmer relationships are becoming increasingly vital in sharing agricultural information and skills transfer. The purpose of this study was to look into the role of information flow through social network analysis in expanding the adoption of cage fish farming in Uganda. Using social network data generated from interviews with cage fish farmers in Lake Victoria, the study revealed a positive association between information-seeking ties through social networks and cage technology awareness. The findings revealed that cage farmers majorly relied on their peers as their primary information sources. Furthermore, the study identified that the most central farmers in networks bridge the information flow between various farmers in different geographical regions. This study adds to the growing body of literature by empirically proving the role of information transfers via social network platforms in cage fish farming, an emerging technology. Importantly, the results of our study can inform the formulation of policy by demonstrating whether formal extension services and informal interactions amongst farmers can be viewed as supportive or distinct entities in order to advance cage fish farming in Uganda.

Keywords: Cage fish farming, extension services, smallholder farmers, social networks, Uganda

Contact Address: Oscar Ingasia Ayuya, Egerton University, Agricultural Economics and Agribusiness Management, Box 536, 20115 Egerton-Njoro, Kenya, e-mail: ingasiaoa@gmail.com

Impact of dietary potassium diformate on the productivity index of *Litopenaeus vannamei* shrimp under tropical conditions

Christian Lückstädt, Nicolas Greiffenstein ADDCON, Germany

Intensive production of the white leg shrimp, Litopenaeus vannamei (Boone 1931), in Central America and SE Asia is estimated to have reached 5.6 million t in 2023. There, bacterial diseases have been identified as a major cause of economic loss to producers. Dietary organic acids, and especially potassium diformate, which is the most widely tested organic acid salt in aquaculture, are among the various alternatives for environmentally friendly and nutritive-sustainable aquaculture approaches, without resorting to the use of antibiotic growth promoters. Dietary potassium diformate (KDF, traded as AQUAFORM[®], ADDCON) has been tested in shrimp aquaculture since 2006 and since then numerous publications and conference contributions on the use of KDF in aquaculture have been published worldwide. This study analysed the average impact of the additive, based on data collected from the published studies on its effects on performance parameters such as feed efficiency and survival rate as well as the productivity index, calculated based on weight gain, survival rate and feed conversion, thus combining the three most important parameters in shrimp production. The final dataset contained the results of 8 published studies in which KDF was included, at dosages ranging from 0.1 % to 0.5 % and covered laboratory trials as well as usage under commercial conditions. Data were subjected to statistical analysis and a significance level of 0.05 was used in all tests. Results are expressed as percentage difference from the negatively controlled white-leg shrimp. The average level of dietary potassium diformate from the dataset in all treated Vannamei shrimp was 0.28%. The performance of the white-leg shrimp, based on feed efficiency was significantly improved by 9.0 % (p < 0.01). Furthermore, the survival rate of the shrimp was also significantly increased (p < 0.01): this time the improvement was more than 16%. Overall, the productivity of shrimp production among the dataset rose highly significantly by more than 45% (p < 0.01). In general, results show significantly improved feed efficiency and survival rates in Vannamei shrimp fed with dietary potassium diformate. These findings support the use of KDF in shrimp feeding as a promising alternative in ecologically sustainable and resource-optimised shrimp production.

Keywords: Potassium diformate, productivity index, Vannamei shrimp

Contact Address: Christian Lückstädt, ADDCON, Parsevalstrasse 6, 06749 Bitterfeld-Wolfen, Germany, e-mail: christian.lueckstaedt@addcon.com

Successful captive propagation of *Coptodon discolour*: An IUCN red list near threatened fish in Ghana

Emmanuel Nyamekye 1 , Loise Sarfo 1 , Emmanuel Frimpong 2 , Margaret Boatemaa 1

¹Consulting in Aquatic Research and Training for Development (CART4D), Ghana ²Virginia Polytechnic Institute and Sate University, Dept. of Fish and Wildlife Conservation, United States

Coptodon discolour, a cichlid endemic to Lake Bosomtwe (Ghana), and a few river basins of southeastern Ghana and western Cote d'Ivoire, has been recently designated "near threatened" on the IUCN Red List. Due to its endemic status and high value in subsistence fisheries, the decline of C. discolour in the wild is both a biodiversity conservation and food security problem. In the light of historical lack of success at breeding and raising the species in captivity, the objectives of this study were to (1) breed C. discolour in captivity, (2) assess acceptability and growth of juvenile *C. discolour* to formulated commercial fish feeds, and (3) assess morphometric parameters, growth, and condition of wild C. discolour held in captivity for breeding. Three treatments (fertilised-fed and unfed, and unfertilised-fed) were established in a feeding trial to determine the acceptability, weight gain, and food conversion ratio (FCR) of offspring on commercial tilapia feed. Periodic sampling for length and weight of wild broodstock were conducted to determine their growth and condition in captivity. Wild C. discolour held in concrete tanks reproduced naturally in grass substrates after two months in captivity. Their offspring readily accepted and grew well on formulated tilapia feed with best FCR (0.8–0.9) observed for the fry and fingerling fed complete diets in unfertilised tanks. The wild brood stock maintained healthy body condition for almost one year, attaining sizes of 100–150 g on a natural diet of algae and aquatic plants, including leaves of water hyacinth (Eichhornia crassipes). This study accomplished all the steps necessary for domestication of a species, showing that strategies to recover C. discolour from spiraling towards extinction would include captive breeding and artificial propagation for, food fish production, wild population enhancements, and possible translocation to suitable extant habitats. Follow-up genetics studies are recommended to characterise wild population viability and guide selection of broodstock for breeding programs.

Keywords: Aquaculture, biodiversity conservation, food security, species diversification

Contact Address: Emmanuel Frimpong, Virginia Polytechnic Institute and Sate University, Dept. of Fish and Wildlife Conservation, 310 West Campus dr, 24061 Blacksburg, United States, e-mail: frimp@vt.edu

Sociocultural indicators in seed production and conservation in the Atrato river basin - Colombian Pacific

Juan Sebastian Valencia Sanchez, Gustavo Adolfo Rodriguez Izquierdo, Gina Marcela Amado Saavedra

Colombian Agricultural Research Corporation, Motilonia Research Center, Colombia

The Atrato River in the Colombian Pacific is one of the three rivers in the world recognised as subjects of rights, this makes the State organise itself to safeguard the social and cultural activities that people develop there. As part of this recognition, the Colombian Agricultural Research Corporation -AGROSAVIA, together with the United Nations Development Program UNDP, have developed a project to produce and conserve seeds respecting their traditions, within which sociocultural indicators were raised, where variables could be identified around the social representations that the Atrato River has, as well as the seeds, governance and forms of ancestral or community food production. These variables were worked on in the municipalities of Lloró, Carmen de Atrato, Vigia del Fuerte and Riosucio, with qualitative tools and techniques such as the observation guide, sound landscapes and field diaries, allowing recognition of the territorialities constructed by people through of time, adapted to climate change, globalisation and the internal armed conflict, which exacerbates the situations of commercialisation and adoption of technological knowledge. We can find that Afro-Colombian, indigenous and peasant groups have strong roots with the territory and with the Atrato River. There are spiritual and traditional beliefs about food production, such as praying to ward off evil spirits, listening to the water to know when it is time to sow or harvest, following the cycles of the moon, and also strengthening the oral tradition in the search for food. To be able to pass on this knowledge to future generations, leaving them with a territorial attachment to the territorial expressions of the Atrato River.

Keywords: Atrato river, bains, conservation, production, sociocultur indicators

Contact Address: Juan Sebastian Valencia Sanchez, Colombian Agricultural Research Corporation, Motilonia Research Center, Cali, Colombia, e-mail: jsvalencia@agrosavia.co

Indigenous knowledge on river health management: The case of river Mayanja, East Africa

Grace Ssanyu¹, Norah Mutekanga¹, Marvious Kiwanuka¹, Maureen Kabasa², Joel Onyango², Andreas Melcher³, Andreas Bauer³, Nzula Kitaka⁴

¹Kyambogo University, Dept. of Biological Sciences, Uganda
²African Centre for Technology Studies, Climate Resilient Economies, Kenya
³BOKU University, Inst. and Cluster for Development Research, Austria
⁴Egerton University, Biological Dept., Kenya

The increasing human population in the sub Saharan Africa has put enormous pressure on the tropical rivers catchments, threatening their functioning and ecological integrity. Despite the vast recognition of integrated water resources management approaches, there are still limitations in their adoption in the local settings due to over reliance on western backgrounds. Yet amidst the deteriorating of tropical river systems, the local communities can provide diverse information that preserved the rivers years back. Such indigenous knowledge should be associated with western science to promote local community involvement in river health management. A qualitative survey on river health status and governance approaches of River Mayanja catchment was done using oral history and local community engagements. From both data sources, there was a clear distinction between the degraded and non-degraded Mayanja river system based on the water physical and biodiversity characteristics. For elders, such knowledge was generated from their livelihoods, climatic and natural disaster experiences. Development needs, western ideologies and lack of understanding of the local knowledge might have influenced the younger generations' knowledge of river system and its governance dynamics. These characteristics agreed with the scientific phenomenon of rivers' dynamics despite the differences in their ontological backgrounds. The spiritual origin of River Mayanja myth contributed tremendously to many rituals and taboos that preserved the river health then. However, the outside interests and loss culture among the youth have led to disbelief of local knowledge and promoted science-based policies which were not fully implemented. These findings exhibit a fundamental connection of R. Mayanja communities and their river which can be tapped to promote acceptance of western knowledge for community river health management strategies with participatory approaches and deeper understanding of the worst-case scenarios to river resource exploitation.

Keywords: East Africa, indigenous knowledge, river health management

Contact Address: Grace Ssanyu, Kyambogo University, Dept. of Biological Sciences, Kyambogo, Kampala, Uganda, e-mail: assanyu@kyu.ac.ug

Integrated agri-aquaculture systems for food security, poverty reduction and resilience in Eastern Africa

Isabel Wagara¹, Andreas Melcher², Felicia Yieke³, David Claeve Waiswa⁴, Abdi Mohammad Hassen⁵, Gabriele Slezak², Elick Otachi¹, Miriam Charimbu⁶, Andreas Bauer², Benson Obwanga⁷, Peter Ayeka¹, Zelalem Bekeko⁸

¹Egerton University, Dept. of Biological Sciences, Kenya
 ²BOKU University, Inst. and Cluster for Development Research, Austria
 ³Laikipia University, Dept. of Literary and Communication Studies, Kenya
 ⁴Gulu University, Animal Production and Range Management, Uganda
 ⁵Haramaya University, College of Agriculture and Environmental Science, Ethiopia
 ⁶Egerton University, Dept. of Crops, Horticulture and Soils, Kenya
 ⁷Laikipia University, Dept. of Biological and Biomedical Sciences, Kenya
 ⁸Haramaya University, School of Plant Sciences, Ethiopia

Smallholder farmers in sub-Saharan Africa are highly vulnerable to food and nutrition insecurity, poverty and environmental degradation due to low agricultural productivity, profitability and sustainability. Agricultural productivity can be increased through integration, intensification and diversification of agri-aquaculture, whereby waste from one part of the system becomes a crucial input in other components in the system. Agri-aquaculture provides a cyclic agriculture approach that focuses on recycling, enhanced productivity and climate change resilience. This paper highlights outputs of the AgriAqua Partnership Project between Kenya, Ethiopia, Uganda and Austria aimed at strengthening knowledge sharing for increased food production and poverty reduction by integrating resilient agri-aquaculture systems (AAS) and promoting triple wins of increasing food productivity, job creation and ensuring sustainable consumption (Zero wastes). Specific objectives of the project were to establish partnerships and networks for integrated agri-aquaculture systems (IAAS) knowledge exchange, identify priority IAAS prototypes in Eastern Africa, and facilitate knowledge and skills transfer to smallholder farmers, with gender and diversity inclusion of women and youths in IAAS technologies.

A review of the IAA status in Eastern Africa showed that despite its huge potential, there is minimal IAA among smallholder farmers in the region. However, farmers undertake different agri-aquaculture activities with little or no integration. The identified country-specific IAAS priority areas included: integrated fish farming with crops, livestock and agroforestry, aquaparks, cage farming, affordable and quality fish feed production in Kenya; land and wa-

Contact Address: Isabel Wagara, Egerton University, Dept. of Biological Sciences, P.O Box 536-20115 Egerton, 20115 Nakuru, Kenya, e-mail: iwagara@egerton.ac.ke

ter resource management in agri-aquaculture integration in Ethiopia; Green Community Model, fish-livestock integration, biogas, bio-slurry for fertiliser in Uganda. The challenges and knowledge gaps in IAAS include poor fish feeds and stocks, fish diseases, toxicity, pesticide residues, while the identified research needs and technology priorities include IAAS knowledge and skills transfer, gender and diversity-inclusive capacity building, community focus, value chain analysis, IAAS innovations, technological focus and upscaling.

Keywords: agri-aquaculture systems, gender and diversity, integration, resilience, smallholder farmers

Impact of multiple socio-ecological stressors in the Purnio river basin, Colombia

 $\begin{array}{l} \mbox{Michael Stummer}^1, \mbox{Hans Peter Rauch}^2, \mbox{Andreas Bauer}^1, \\ \mbox{Andreas Melcher}^1 \end{array}$

¹BOKU University, Inst. of Development Reserach, Austria ²BOKU University, Inst. of Soil Bioengineering and Landscape Construction, Austria

This study analyses the multiple lines of stressors affecting Central Colombia's Magdalena River and Purnio River. It provides a comprehensive overview of the current state of this socio-ecological system and connects it with the perceptions of the local population. Employing a multi-scale approach, this thesis investigates the hydro-morphological and abiotic parameters of the Magdalena River's tributary rivers, tracing their course from the tropical dry forest where the river originates to its confluence with the mighty Magdalena River. Cross-sectional analyses of hydro-morphological data of 28 sampling sites, collecting 89 abiotic samples. Additionally, 35 face-to-face interviews were conducted with the local people.

In the upper reaches of these rivers, the ecosystem remains remarkably pristine, characterised by an untouched river system with unhindered bed and bank dynamics. However, as one moves downstream, human settlements become denser, and expansive grazing and agricultural areas encroach upon the landscape. This shift brings an influx of sewage runoff into the river, severely limiting the river's natural dynamism.

As one travels along the river's course, abiotic data reveals a concerning trend: electrical conductivity and total dissolved solids increase as oxygen concentration decreases. Many of the regional population doubts the river's water quality, attributing it to cattle breeding, grazing, waste disposal, and wastewater discharge. These impacts were starkly evident during the field survey.

The findings of this research have significant implications for our understanding of river systems in tropical dry forests. They can serve as a valuable management tool, promoting the health of ecosystems and sustainable agricultural practices. Ultimately, these efforts contribute to preserving a healthy river system and maintaining good water quality, benefiting the environment and local communities.

Keywords: Abiotic data, water quality

Contact Address: Michael Stummer, BOKU University, Inst. of Development Reserach, Peter-Jordan-Straße 76/1, 1180 Vienna, Austria, e-mail: michael.stummer@students.boku.ac.at

Water and its biological resources sustainability in tropical developing countries: Aquatic ecosystems health assessment

IDRISSA KABORÉ¹, OTTO MOOG², ADAMA OUEDA³, ANDREAS MELCHER⁴ ¹Université Joseph Ki-Zerbo, Lab. de Biologie et Ecologie Animales (LBEA), Burkina Faso ²BOKU University, Inst. of Hydrobiology and Aquatic Ecosystem Management, Austria ³University of Ouahigouya, Burkina Faso

⁴BOKU University, Inst. and Cluster for Development Research, Austria

To response to ongoing threats from human pressures and climate changes, water managers and users need a visual tool that provide accurate information of waterbodies health for decision making to promote sustainable management practices. However, there is a lack of less sophisticated tools, such as biotic score, to assess the health of aquatic ecosystems, especially in Burkina Faso. To fill this gap, we developed an approach based on a macroinvertebrates scoring system to monitor the aquatic ecosystems health. Following a multi-habitat sampling approach, macroinvertebrates were collected with a hand net, and identified using taxonomic manuals and keys. Key environmental parameters, both physico-chemical and hydro-morphologic, were recorded. For data analysis, benthic macroinvertebrates were scored following guide scores and experts' consensus. In total, more than 70 taxa of macroinvertebrates were recorded. Most of these taxa were identified at family level, and taxa scores sensitivity to human disturbances ranged from 1 (very tolerant) to 10 (highly sensitive). We found that all taxa found are well represented in western African freshwaters. The Burkina Botic Scores (BBIOS) and Burkina Biotic Score Average Per Taxa (BBIOS/ASPT) revealed a strong and significant correlation with environmental variables including anthropogenic pressures types (r=|0.6|; p<0.01) rending it more robust for monitoring aquatic ecosystems. With this effective and comprehensive tool, we encourage West African local water managers to use macroinvertebrates at family taxonomy resolution for bioassessment and biomonitoring programmes due to its cost-benefits (e.g. ease of sampling and identification of specimens) and its limited taxonomic knowledge. This study yielded an unprecedented tool that can be used or adapted to monitor also other tropical aquatic environments in West Africa, and may help to preserve water as biological resource for future generations.

Keywords: Aquatic ecosystems, biotic indices, dryland, ecological integrity, sustainability

Contact Address: Idrissa Kaboré, Université Joseph Ki-Zerbo, Lab. de Biologie et Ecologie Animales (LBEA), Ouagadougou, Burkina Faso, e-mail: ikabore16@yahoo.fr

Nexus of climate change, smallholder farmers food security and rural-out migration in Nepal: From fields to new horizons

Giri Prasad Kandel¹, Miroslava Bavorová¹, Ayat Ullah¹, Sylvester Amoako Agyemang¹, Prajal Pradhan²

¹Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Economics and Development, Czech Republic ²Potsdam Institute for Climate Impact Research, Germany

Climate change affects the livelihood and food security of Nepalese smallholder farmers. Rural out-migration has remarkably increased, rising to 4.35 persons per 1000 inhabitants in 2022. The rural out-migration could have potential implications for agricultural production in the country. Therefore, the objective of this study was to analyse the climate change, food security, and migration nexus. We aimed to identify the factors influencing rural-out migration, including climate change, and the impact of migration on household food security. The study analysed 400 selected households using multistage sampling in three agro-ecological zones: highland (mountainous region), midland (hilly region), and lowland (terai region). The data were analysed using binary probit, propensity score matching, and endogenous switching regression models. The results showed that climate change, age, education, social group, and off-farm activities significantly increase the probability of rural out-migration. The endogenous switching regression model revealed that rural-out migration significantly improved households' food security. Although rural out-migration enhances the food security status of smallholder farmers in the short term, this is not a sustainable solution. In the long term, rural out-migration may exacerbate food insecurity due to a lack of labour for agricultural productivity. The main reasons for migration included seeking employment opportunities, improved livelihoods, access to education, fertile agricultural land, and adaptation to climate change. Our research highlights the urgent need for robust policies encouraging smallholder farmers to stay on their land and promote rural opportunities. Based on our findings, we propose comprehensive strategies that integrate both on-farm and off-farm employment opportunities and investments in education and agricultural innovation to anchor smallholder farmers and strengthen food security.

Keywords: Food security, livelihoods, sustainable development goals

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: carlous.girish49@gmail.com

Contribution to the identification of responses to the effects of socio-ecological stressors on aquatic ecosystems in Burkina Faso

Vincent-Paul Sanon¹, Laura Hundscheid², Patrice Toé¹, Stefan Vogel³, Andreas Melcher⁴

¹University Nazi BONI (UNB), Inst. for Rural Development (IDR), Burkina Faso ²BOKU University, Dept. of Sustainable Agricultural Systems, Austria ³BOKU University, Inst. for Sustainable Economic Development, Austria ⁴BOKU University, Inst. and Cluster for Development Research, Austria

Burkina Faso has adopted dam construction as a strategic response to water scarcity, making it one of the countries with the highest concentration of dams in sub-Saharan Africa. However, the sustainability of these water reservoirs is a major challenge. This work aims at analysing how the effects of socio-ecological stressors on aquatic ecosystems imply responses towards sustainable fisheries and water resources management. Multi-evidence approach was used. We conducted both desk research to collect secondary data and empirical research to gather primary data through strategic simulation, qualitative interviews, and structured interviews.

The research contributed to understanding the complex interaction of multiple stressors that influence the sustainability of inland fisheries in Burkina Faso's aquatic ecosystems: the current decrease of total annual precipitation and the increase of yearly precipitation variability due to climate change result in decreased water level, which impacts, in turn, fish abundance and average size; fish productivity, abundance, and average size were shown as the biotic indicators that are most recognised as being impacted nowadays by climate change in the country; The massive construction of dams and intensive agriculture have affected the status of aquatic ecosystems and fish; the profitability associated with the lack of enforcement can enhance overexploitation since it drives a feedback loop between the increase in the number of fishers, fishing rates, incomes, and profits.

Improving education, management enforcement, infrastructures, alternative livelihoods, energy production, and support towards sustainable livelihoods were identified as the responses i.e., potential actions for sustainable management of aquatic ecosystems.

The understanding, from diverse perspectives, of socio-ecological stressors helped better integrate water and fish-related ecosystem services contributions to human wellbeing, e.g., secure livelihood and food access, and the need to preserve these resources in the long term through a better knowledge of their interaction and possible effective societal responses.

Keywords: Burkina Faso, responses, stressors, sustainability, water resources

Contact Address: Vincent-Paul Sanon, University Nazi BONI (UNB), Inst. for Rural Development (IDR), Bobo-Dioulasso, Burkina Faso, e-mail: svpaulus@yahoo.fr

A transdisciplinary approach to hydro-meteorological risk reduction in an informal semi-urban neighbourhood in El Salvador

Christian Pyerin¹, Hans Peter Rauch¹, Stephan Hörbinger¹, Sandra Gutiérrez Poizat², Carlos Ernesto Grande-Ayala²

¹BOKU University, Inst. of Soil Bioengineering and Landscape Construction, Austria ²Universidad Centroamericana José Simeón Cañas, Dept. of Spatial Organization, El Salvador

Informal neighbourhoods face complex social, economic and environmental challenges, of which many are related to uncoordinated land and water management. Mitigation measures are mostly implemented by individual residents, but due to landscape connectivity, these measures often cause downslope impacts. Reduced vegetation and surface sealing combined with the lack of a sewage system lead to high surface water runoff, which results in increasing pluvial flooding, erosion, and landslides. Moreover, the effects of climate change increase hazard intensities and therefore, hydrometeorological risks.

This study presents a transdisciplinary land and water management approach based on interviews, field surveys and numerical modelling to identify appropriate Naturebased Solutions (NbS) for informal semi-urban neighbourhoods to reduce hydro-meteorological risks.

Interviews and transect walks served to delineate the study area and identify challenges and relevant stakeholders. Participatory mapping utilised local knowledge to identify surface runoff paths and problem sites and served as a basis to discuss, design, and locate potential NbS. Proposed solutions include low-cost, self-implementable NbS and urban planning measures which require the involvement of other actors.

The use of the coupled hydrological-hydrodynamic model HEC-RAS serves to describe the surface water runoff conditions in selected precipitation events by utilising Rain-on-Grid modelling, and to quantify the potential effects of suggested NbS. The idea is to validate the model through flooding depths of historical precipitation events, which were determined during the participatory mapping workshop.

The results are expected to demonstrate the ability of this conceptual approach to utilise local knowledge to design implementable and effective NbS to reduce hydrometeorological risks. Furthermore, this study will show how local knowledge and participatory mapping can be used to validate pluvial flooding models. The quantification of the effects of proposed NbS can support the implementation of suggested measures.

Keywords: Hydro-meteorological risk, hydrological-hydrodynamic modelling, informal neighbourhood, nature-based solutions, participation, transdisciplinary research, urban runoff

Contact Address: Christian Pyerin, BOKU University, Inst. of Soil Bioengineering and Landscape Construction, Franz-Schwackhöfer-Haus, Peter-Jordan-Straße 82/III, 1190 Vienna, Austria, e-mail: christian.pyerin@yahoo.com

Integrating field observations and community insights to evaluate mangrove ecosystem health and conservation strategies in Funzi Bay, Kenya

TILL AYASSE¹, BERNERD FULANDA², ANDREAS MELCHER¹

¹BOKU University, Inst. for Development Research, Austria ²Pwani University, Dept. of Biological Sciences, Kenya

Mangrove ecosystems are vital coastal habitats that provide various ecological services and support the livelihoods of coastal communities. These ecosystems, however, face significant pressures from both human activities and natural processes. This study presents an interdisciplinary approach to assess the health and conservation strategies of mangrove ecosystems in Funzi Bay, Kenya, integrating scientific research with local insights to enhance our understanding of these complex systems. The research uses remote sensing for quantitative analysis and detailed field observations to gain qualitative insights into the mangrove structure, environmental pressures, and socioeconomic dependencies in Funzi Bay. Remote mapping techniques assess land use and environmental pressures in a 15 km radius around the mangroves, while transect surveys analyze forest structure, species composition, and the impacts of tree cuttings. The local community and fishermen contribute through questionnaires, helping to understand the socio-economic ties with the mangrove ecosystems. In addition to these methods, a system dynamics model will evaluate the impacts of various pressure drivers on the mangrove system, aiming to inform effective conservation strategies and policy decisions that align with sustainable development goals. The study aims to enhance the resilience of mangrove ecosystems by incorporating diverse types of evidence, including biological, geographical, and sociological data, to address the complexities of these ecosystems. The anticipated outcomes include a assessment of the mangrove forest structure, the ecological characteristics, and the environmental pressures affecting the mangrove ecosystem of Funzi bay. Insights from local communities will show socio-economic interdependencies and can be used for strategies to balance conservation efforts with community livelihoods. This will contribute to a broader understanding of the role of mangrove ecosystems in coastal resilience and the importance of integrating scientific research with local knowledge for effective conservation and management strategies. By using a methodological approach that integrates different sources of evidence, this thesis will provide a complete view of the ecological, socio-economic, and environmental dynamics, helping with future efforts to preserve these critical ecosystems for the benefit of both nature and local communities.

Keywords: Human pressures, Kenya, reforestation, SDGs, sustainability

Contact Address: Till Ayasse, BOKU University, Inst. for Development Research, Wiedner haupstraße 125/38, 1190 Vienna, Austria, e-mail: till.ayasse@students.boku.ac.at

Resilient interfaces for integrated land and water resource management of various catchments in Ethiopia, Kenya, Uganda, Mozambique, and Burkina Faso

Andreas Melcher¹, Gabriel Bönnhoff¹, Zerihun Amare², Dessie Assefa Belete², Abdi Mohammad Hassen³, Adama Oueda⁴, João Paulino⁵, Grace Ssanyu⁶, Nzula Kitaka⁷, Isabel Wagara⁷

¹BOKU University, Inst. for Development Research, Austria

²Bahir Dar University, Inst. of Disaster Risk Management and Food Security Studies, Ethiopia

³*Haramaya University, College of Agriculture and Environmental Science, Ethiopia* ⁴*University of Ouahigouya, Burkina Faso*

⁵University of Zambeze (FCSH), Dept. of Economics Sciences, Mozambique

⁶Kyambogo University, Dept. of Biological Sciences, Uganda

⁷Egerton University, Department of Biological Sciences, Kenya

This paper examines the role of land-water interface zones – including buffer strips and adjacent agricultural areas near streams, rivers, wetlands, and lakes – across various catchments in Ethiopia, Kenya, Uganda, Mozambique, and Burkina Faso. The project aims to enhance our understanding and application of ecosystem services and agroecology to improve the health of critical natural habitats and ecosystems by reviewing existing literature, experimental data, and pilot studies.

Central to our research is a comprehensive approach to catchment management that addresses climate change impacts and socio-ecological dynamics. Specific attention is directed towards managing entire catchments to mitigate severe erosion, enhance carbon capture, improve water infiltration and retention, and raise groundwater levels to manage droughts and floods better. Additionally, we focus on nitrogen and phosphorus management to improve water quality for human use, maintain ecosystem health, and boost fish production.

Gender and diversity considerations are woven throughout the project, particularly in agriculture, forestry, and water quality. The paper aims to adapt to increasing global uncertainties by refining methods to understand trends and mechanisms that affect socio-ecosystems and sustain global well-being. The Sustainable Development Goals (SDGs) serve as a framework for monitoring the project's impact and assessing progress towards understanding and implementing Agenda 2030.

Five pilot projects, represented by our Africa-UniNet partners, will provide the practical material for catchment management using ecosystem-based

Contact Address: Gabriel Bönnhoff, BOKU University, Institute for Development Research, Dänenstrasse 4, 1190 Vienna, Austria, e-mail: gabriel.boennhoff@students.boku.ac.at

approaches and nature-based solutions. How these global change-relevant activities can be managed and established at the catchment level will be discussed based on other projects handed into this call by African partners. This will expand the international and geographical perspective while increasing the knowledge base:

(1) Gender-specific, adaptive capacity on Climate Change and Food Security. Status: A catchment approach to agroforestry land-water systems.

(2) Integrated Agri-Aquaculture Systems for Food Security and Poverty Reduction.

(3) Strengthening Research and Adaptive Management of Buffer Zones in Lake Tana catchment.

(4) Strengthening community-based research for river health and climate change mitigation in Eastern Africa.

(5) Rural women productive resources and their resilience to climate changes.

Keywords: Agroecology, climate change mitigation, community-based research, ecosystem management, land, SDG, water

Multiple lines of evidence for assessing human pressures on aquatic ecosystems in Kenya and Uganda

Andreas Bauer¹, Nzula Kitaka², Grace Ssanyu³, Maureen Kabasa⁴, Joel Onyango⁴, Norah Mutekanga³, Lorine Auma², Gabriele Slezak¹, Andreas Melcher¹

¹BOKU University, Inst. of Development Research, Austria

²Egerton University, Biological Dept., Kenya

³*Kyambogo University, Dept. of Biological Sciences, Uganda*

⁴African Centre for Technology Studies, Climate Resilient Economies, Kenya

Across the world, pressure to use evidence-based environmental management is increasing, but little guidance exists as to what 'evidence-based' actually means. Accurate and informative methods for evidence synthesis that are simple and inexpensive to implement would significantly increase the ability to use scientific research results better to manage land/water resources in sub-Saharan Africa, particularly Kenya and Uganda. Increasing industrial and agricultural pollution, accompanied by climate change and extreme weather effects, severely threatens human and ecosystem integrity. Established water quality monitoring practices in Kenya and Uganda predominantly rely on short-term indicators, failing to provide a holistic, long-term perspective. Therefore, our research methodology aims to (1) advance and promote multiple lines of eco-evidence synthesis methods and (2) strengthen community-based research for river health and climate change mitigation in Eastern Africa. In doing so, we established a cause-effect database. We synthesized international and local literature, expert and traditional community knowledge, and empirical abiotic and biotic (benthic invertebrates) field data. Our results highlight the potential of socio-ecological evidence to complement and enhance cause-effect chains based solely on scientific literature. A significant correlation between drivers of agriculture, industry, urbanisation, and climate change as critical impacts for freshwater ecosystem degradation. In addition, cause-effect models operationalize complex socio-ecological findings into an accessible format to facilitate socio-ecological and environmental mitigation within a broad audience from local communities to policy. They address the need to respect aquatic ecosystems and their resilience and integrate community engagement and indigenous knowledge when developing sustainable socio-ecological strategies for effective ecosystems as opportunities to explore long-term perspectives in environment management in Uganda and other regions of sub-Saharan Africa.

Keywords: Cause-effect models, community-based methods, freshwater ecosystems, multiple-lines of evidence, water quality

Contact Address: Andreas Bauer, BOKU University, Inst. of Development Research, Peter-Jordan-Strasse 76/I, 1190 Vienna, Austria, e-mail: andreas.bauer@boku.ac.at

Evaluating drought management strategies in Andean irrigation systems

María Augusta Bermeo, Rolando Célleri

University of Cuenca, Department of Water Resources and Environmental Sciences, Ecuador

In the Ecuadorian Andes, approximately 70 percent of people in rural communities rely on agriculture and livestock for their livelihoods. Recently, prolonged, and intensive droughts have caused significant negative impacts on agricultural activities because farmers are not ready to cope with this natural phenomenon. This is due to a lack of knowledge about agricultural water management, the high implementation cost of conventional drought management strategies, and the lack of data about their irrigation schemes. This has led to decreased production and has had profound economic, social, and labour repercussions within these communities. In this study, we worked together with irrigation water user associations to identify key cost-effective water management strategies that farmers can implement. Using farmers' knowledge about drought impact on water availability in the headwaters we reconstructed the hydrological and hydraulic conditions of severe and mild droughts. With this information, we developed scenarios for managing irrigation water effectively. Additionally, we conducted interviews with 45 water users to identify strategies for water management under droughts at the plot scale. A literature review was carried out to identify successful strategies implemented elsewhere. Strategies were ranked from low cost, fast implementation to high cost, highly technical. We used models to identify the impact of these strategies. Preliminary findings indicate that simple strategies (e.g., irrigation scheduling) will have a moderate impact on reducing the impact of droughts and that the best adaptation will require a combination of measures and strategies (e.g., building small-scale reservoirs, and adoption of rainwater harvesting systems). We also identified strategies that will never be implemented by farmers due to their complexity. A combination of soft data, modelling, economic costing, and farmer's participation is essential to generate sustainable solutions to droughts.

Keywords: Andes, drought, irrigation, management, strategies

Contact Address: María Augusta Bermeo, University of Cuenca, Department of Water Resources and Environmental Sciences, Av. Victor Albornoz y Calle de los Cerezos, Cuenca, Ecuador, e-mail: augusta.bermeo@ucuenca.edu.ec

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Climate smart agriculture adoption and climate change adaptation strategies

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Analyzing the nexus between agricultural knowledge management and climate change adaptation, vulnerability status of rural women in Ethiopia

Fentaw Teshome Asnakew^{1,2}, Raquel Guimaraes², Beneberu Assefa Wondimagegnhu³, Girma Gebresenbet⁴, Getaw Tadesse⁵, Koyachew Enkuane¹

¹Bahir Dar University, Dept. of Rural Development, Ethiopia
²International Institute for Applied Systems Analysis (IIASA), Population and Just Societies Program, Austria
³Policy Study Institute, Economics, Ethiopia
⁴Swedish University of Agricultural Sciences (SLU), Sweden
⁵AKADEMIYA2063, Ethiopia

Effective sharing and management of climate knowledge in rural communities are crucial for enhancing climate adaptation practices, fostering inclusive growth, and reducing the vulnerability of marginalized groups to climate change. This, in turn, contributes to creating a safe and healthy environment. The primary objective of this paper is to analyse the relationship between agricultural knowledge management, climate change adaptation, and the vulnerability status of rural women in Ethiopia.

Our food and agriculture systems face significant challenges in sustainably producing sufficient, nutritious, and affordable food. Ethiopian farmers are struggling with climate change events such as droughts, erratic rainfall, floods, and food shortages. For example, in October 2023, over 24 people died, 23,000 were displaced by floods, and 2,000 were displaced by drought. Currently, the most vulnerable groups, particularly women, have limited access to agricultural knowledge management, innovation, and public services like short-term training, knowledge sharing, and digital communication. Despite more than 52 drought-resistant crop varieties being released by Amhara Regional Farmers, there is very restricted knowledge or scientific information about climate change; instead, it is often attributed to supernatural causes. Providing inclusive climate information access to rural communities can significantly contribute to global efforts to mitigate climate change.

1. To analyse existing climate change adaptation practices in response to shocks at the rural household level in Ethiopia, using a gendered approach.

2. To assess the status of agricultural knowledge management (climate knowledge) in northern Ethiopia.

3. To evaluate the climate change vulnerability status of rural women in northern Ethiopia.

Contact Address: Fentaw Teshome Asnakew, Bahir Dar University, Dept. of Rural Development, Bahir Dar, Ethiopia, e-mail: fentawta@gmail.com

4. To identify the determinants of climate change adaptation practices, climate knowledge, and the vulnerability of women in northern Ethiopia.

5. To evaluate existing social protection measures that promote adaptation to climate change in northern Ethiopia.

Both qualitative and quantitative methods were employed, with interviews conducted with 664 rural households. Focus group discussions (FGD) and key informant (KI) interviews were held and analysed using STATA. Both inferential binary probit models for climate adaptation practices of farm households and descriptive statistics were applied. Secondary data from NASA's Power Climate dataset were used for each selected study district.

Keywords: Climate adaption, climate information, rural household, rural women and food system

Agriculture a risky business: Risk transfer solutions as a cornerstone for resilient agri-food systems?

JOACHIM HERBOLD

University of Hohenheim, Germany

Agricultural production is prone to a multitude of risks, including natural hazards, pests and diseases as well as political risks. Climate change is aggravating most of these risks, jeopardising food security.

Suitable adaptation strategies to climate change for the agricultural sector are, hence, indispensable. In the last decade agricultural research has focused on adapted production systems, incorporating new crop types, improved crop varieties, fertilisation, soil and pest management. Underdeveloped, however, remain risk transfer instruments, especially in the tropics and subtropics. They transfer risks of substantial economic impact on farm, village or regional level to third parties like insurances or funds. Ag economic research in the tropics and subtropics has dealt with this topic only sporadically; hence, more research is needed.

During the latest UN climate change conferences, the need for risk transfer instruments was acknowledged by various stakeholders. In consequence, first initiatives and instruments like the "Loss and Damage Fund" and the "Global Shield against Climate Risks" were launched internationally at COP 28 in 2023 and at COP 27 in 2022 respectively. The big challenge of these initiatives is the implementation of concrete risk transfer instruments on supranational, national and regional level. A contractual framework with clear procedures and legally proof regulations has to be developed and implemented. For instance, covered production/items, monetary values, geographical scope and indemnification mechanisms have to be defined. Such instruments will have great relevance for risk management in agriculture, especially in the context of smallholders with limited access to commercial risk transfer solutions.

Against these developments, the presentation aims to provide an overview about presently applied and potential risk transfer concepts and their respective instruments to cover the agricultural production (crops, grassland, livestock, agroforestry) and infrastructure (buildings, machinery, equipment, fences). The potential of new technologies like remote sensing and modelling will be critically assessed.

Keywords: Agriculture, funds, insurance, risk management, risk transfer instruments

Contact Address: Joachim Herbold, University of Hohenheim, 70593 Stuttgart, Germany, e-mail: drjoachimherbold@outlook.de

Developing agroforestry product value chains for landscape and livelihoods resilience: Insights from a multi-chain approach in Eastern Province, Rwanda

Dietmar Stoian¹, Jane Mutune², Amani Rukundo Nshutiyimana², Egide Gwaneza², Phocas Gahamanyi²

¹*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Sustainable and Equitable Value Chains, Germany*

²*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Country Office Rwanda, Rwanda*

Rwanda's Eastern Province is subject to prolonged dry spells, exacerbated by climate change. Agroforestry and silvopastoral practices can increase the resilience of land use and livelihood systems. For broad-based planting of trees on farms, smallholder farmers need economic incentives in addition to the prospective use of tree-based products for household consumption. Developing value chains of agroforestry products can provide such incentives through value adding and upgrading processes and products, with smallholders organised in cooperatives as a prerequisite for their successful engagement in value chains. Within the framework of the Transforming Eastern Province through Adaptation (TREPA) project, a multi-chain approach allows farmer cooperatives to assume a pivotal role in developing agroforestry product value chains based on the following steps: 1) Rapid market appraisal for promising agroforestry products; 2) Prioritisation of value chains for value adding and upgrading; 3) Enterprise survey to identify cooperatives and other small and medium enterprises (SMEs) engaged in the targeted value chains; 4) Capacity needs assessments among the enterprises identified; and 5) Capacity building for climate-resilient agribusiness development involving cooperatives and other SMEs.

The multi-chain approach led to the prioritisation of three types of value chains, namely tree crops, bee products, and fodder. For each chain, we assessed business capacities and skills among cooperatives and other SMEs operating in Eastern Province, and identified gender- and age-differentiated employment and income opportunities along the value chain nodes. Out of a total of 248 cooperatives and SMEs, 101 were found to have a minimum set of business assets and skills for upgrading to the next level. We developed a tailored capacity building program, including the facilitation of business plans, training on quality production and value adding, and investments in machinery and

Contact Address: Dietmar Stoian, The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Sustainable and Equitable Value Chains, c/o Global Crop Diversity Trust, Platz der Vereinten Nationen 7, 53113 Bonn, Germany, e-mail: d.stoian@cifor-icraf.org

equipment. Access to client-specific climate and market information is facilitated through digital tools. Contacts with service providers were brokered for customized technical assistance, business development support, and access to innovative financial products. The approach and the results achieved to date are relevant for other programmes seeking to strengthen landscape and livelihoods resilience by developing portfolios of agroforestry value chains in support of diversified land use and livelihood strategies.

Keywords: Agroforestry, bee products, climate adaptation, fodder, tree crops, value chains

Farmer-led innovation systems for climate resilience: Insights from farmers' choices of adaptation priorities and preferences

 $\begin{array}{c} {\rm Priscilla\;Kephe}^1, {\rm Abel\;Chemura}^2, {\rm Siyabusa\;Mkuhlani}^3, {\rm Kingsley\;Ayisi}^4, \\ {\rm Brilliant\;Petja}^5 \end{array}$

¹Julius Kühn Institute, Institute for Strategies and Impact Assessment, Germany

²University of Twente, Dept. of Natural Resources, The Netherlands

³International Institute of Tropical Agriculture (IITA), Kenya

⁴University of Limpopo, Risk and Vulnerability Science Centre, South Africa

⁵Water Research Commission, South Africa

Agriculture is constantly challenged by increased variability and changing climate, leading to crop failures, and declining production. Farmers are expected to respond and adapt to these challenges to ensure yield stability and continuity in production within this setting. This study assessed the perception of smallholder farmers to a changing climate and their coping and adaptive strategies and identified potential coping strategies for future production through priority ranking. Using participatory approaches, 600 smallholder farmers were sampled across three agroecological zones in Limpopo, South Africa. The data collected were on support received, climatic factors affecting them, and how they adapt and can adapt in the future under different farming practices, conservation agriculture, diversification, new technologies, and different timing for farming practices. Descriptive statistics and factor analysis were used for data analysis. Results showed that all farmers are aware of increased climate change and variability, with changes in rainfall patterns being the most prominent experienced by all farmers. Extreme floods, droughts, and waterlogging prompted 84.5 % of farmers to adjust their farming practices drastically. Climate change and variability influenced decisions regarding crops to plant and the weeding method to use by 86 % of farmers. Coping measures mostly used include a change in planting dates and weeding techniques. Furthermore, out of 15 adaptation strategies implemented, farmers ranked crop residue application as mulch on bare soil as the most essential strategy vital for future production, followed by conservation agricultural practices. The use of slow-release fertiliser ranked the least. Even though there were differences in the number of farmers experiencing climate extremes in different agroecological zones, the Bonferroni test results showed no statistically significant differences among farmers regarding their perceptions and responses to climate change and variability. However, there is room for better adaptation if the government intensifies agricultural extension activities and encourages planting different varieties of similar season length that the farmers are used to working with, enhancing weather forecasting, and making the information available to farmers to enable them to adjust to changing planting dates. In that respect, there is a need to integrate adaptation strategies to match the area's socio-economic and cultural characteristics.

Keywords: Adaptation, crop management, perception, priority ranking, risk

Contact Address: Priscilla Kephe, Julius Kühn Institute, Institute for Strategies and Impact Assessment, 14532 Kleinmachnow, Germany, e-mail: priscilla.kephe@julius-kuehn.de

Farmers' adaptation strategies to extreme weather events: Insights from an insurance game experiment

Alexander Cano¹, Margarita Gáfaro², César Mantilla³, Lina Restrepo-Plaza⁴

¹*Justus Liebig University Giessen, Intern. PhD Program for Agricultural Economics, Bioeconomy and Sustainable Food Systems, Germany*

²Banco de la República de Colombia, Colombia

³*Universidad Loyola Andalucía, Loyola Behavioral Lab, Spain*

⁴Universidad Europea de Valencia, Departamento de Empresa, Spain

Climate change significantly impacts the agricultural sector, leading to changes in weather patterns, land suitability, water availability, and crop yields; and extreme weather events, like landslides and droughts, are becoming more frequent and severe, jeopardising the productive capacity of farmers. Understanding adaptation responses to these events is crucial for developing effective adaptation strategies. In this study, we conducted a lab-in-the-field experiment with 360 farmers from 12 villages in central Colombia subject to either several landslides, droughts, or none (i.e., a control group). We designed and implemented an insurance game:participants must allocate some endowed tokens between production and protection against three types of shocks: landslides, droughts, and pests. After the farmers had decided on how to invest their tokens, a six-sided die was used to represent which of the possible shocks might occur. Three faces represented the shocks they were insuring against while the other three represented that none of them would occur. Depending on how they invested and the outcome of the die, they received payouts representing the returns on their investment. We find that, despite the prevalent risk associated with droughts, farmers demonstrated a greater propensity to invest in landslide protection measures. This inclination seemed to be influenced by past experiences and immediate environmental conditions, notably the occurrence of heavy rainfall as a consequence of the La Niña phenomenon during the study period, which likely heightened concerns about landslide events. This result reveals that the more salient events to protect against may be driven by recency rather than long-term magnitude.

Keywords: Climate change adaptation, Colombia, experimental game, extreme weather events, 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

Farmers' perception of the efficacy of current climate risk adaptation and mitigation strategies on agriculture in the Gambia

Sheriff Ceesay^{1,3}, Fatima Lambarraa-Lehnhardt², Mohamed Ben Omar Ndiaye³, Diatou Thiaw³, Mamma Sawaneh⁴

- ¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Senegal
- ²Leibniz Centre for Agricultural Landscape Research (ZALF), Farm Economics and Ecosystem Services, Germany
- ³Cheikh Anta Diop University (UCAD), Fac. of Economics and Management Sciences (FASEG), Senegal
- ⁴University of The Gambia (UTG), School of Agriculture and Environmental Health Sciences, Gambia

Agricultural systems face significant challenges due to climate change, which require effective adaptation strategies. This study explores Gambian smallholder farmers' perceptions regarding the effectiveness and effect of adaptation and mitigation strategies within the context of the farming system. A survey with smallholder farmers in the Gambia was conducted to assess their perceptions of the efficacy of climate risk adaptation and mitigation strategies. The effectiveness of these strategies was evaluated by asking farmers to rate them on a Likert scale. To quantify farmers' perceptions, a perception index was developed. This index was calculated by assigning numerical values to the Likert-scale responses provided by farmers for each strategy. Synthesizing these results, a perception index is established at 0.66. The finding revealed that smallholder farmers consider both adaptation and mitigation strategies crucial for alleviating climate change's impact on agricultural productivity. Adaptation strategies such as changing crops to livestock, using inorganic fertilisers, pesticide application, irrigation, praying, use of insurance, wage migration, assistance from government/non-governmental organisations, and mitigation strategies such as changing seed quality and stop cutting trees are perceived as effective strategies. Furthermore, the study also examines the economic, social, and environmental effects of the adaptation and mitigation measures by assessing farmers' expectations with the implementation of different strategies, thus providing a holistic understanding of the outcome of implementing various strategies in agricultural practices. The result highlights the significance of comprehending farmers' perceptions to enhance the adoption of effective climate risk adaptation and mitigation strategies in evolving farming and land management paradigms. The

Contact Address: Sheriff Ceesay, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Dakar, Senegal, e-mail: ceesay.s@edu.wascal.org

study highlights the importance of integrating farmers' perceptions into climate change adaptation and mitigation strategies to meet the needs of local agricultural communities better. By acknowledging and addressing farmers' realities, policymakers can better tailor interventions for improved effectiveness and sustainability in the face of global climate change. This research offers valuable insights into the efficacy of adaptation and mitigation strategies in The Gambia, emphasising the crucial role of farmer engagement in enhancing adaptation efforts in agriculture.

Keywords: Adaptation, climate risk, efficacy, Gambian agriculture, mitigation, perception index

Understanding the potential of adjusted water management to lower the global warming potential of rice in India

ANKITA PAUL, ANTHONY M FULFORD, PAVAN KUMAR YEGGINA, AMIT SRIVASTAVA International Rice Research Institute (IRRI), South Asia Regional Centre, India

Agricultural production and food security are facing challenges due to weather extremes and climate change. While rice is commonly grown in Asia's most productive cropping systems, its irrigation water demand is high, and the water use efficiency is relatively low when continuously flooded (CF). Climate change will likely make it more difficult to sustain yields with the currently available management practices. Implementing alternate wetting and drying (AWD) irrigation rather than CF reduces rice production's water footprint and creates aerobic soil conditions that limit methanogenesis. However, the potential rise in nitrous oxide (N_2O) emissions during the aerobic phase should be considered when assessing greenhouse gas (GHG) emissions and the overall global warming potential (GWP) of this method. Working with smallholders (< 0.5 ha) on a pilot study in Haryana, India, we compared the GHG emissions between AWD and CF irrigation of puddled transplanted rice (TPR) in kharif season (July-October) of 2023. Results revealed a very distinct and lower seasonal range of CH_4 flux for AWD (12–17 kg ha⁻¹) compared to CF (33–57 kg ha⁻¹). However, the seasonal range of N_2O emissions for AWD $(0.74-0.99 \text{ kg ha}^{-1})$ exceeded that of CF $(0.50-0.88 \text{ kg ha}^{-1})$. Despite a greater seasonal N₂O flux, rice grown under AWD exhibited a lower average seasonal GWP of 582 kg CO_2 -eq ha⁻¹ compared to CF of 1177 kg CO₂-eq ha⁻¹, representing an approximately 51 % reduction in the GWP of TPR by shifting to AWD as an irrigation management strategy. Building on these promising results, we have expanded our evaluation of AWD in the kharif season of 2024 to include smallholders in Madhya Pradesh and Andhra Pradesh, states with different irrigation water management options. We aim to enhance remote sensing methodologies to optimise Monitoring, Reporting, and Verification (MRV) of low-emission practices, including standard operating procedures and model scaling. Additionally, we plan to complement on-field measurements with biogeochemical modelling (e.g., DNDC) to understand AWD's potential across different states of India.

Keywords: Alternate wetting and drying, DNDC, methane, MRV, remote sensing

Contact Address: Ankita Paul, International Rice Research Institute (IRRI), South Asia Regional Centre, Collectory Farm, 221106 Varanasi, India, e-mail: ankita.paul@irri.org

Coping and social cohesion mechanisms in addressing climate change and land degradation in Ghana

Harry Quaye Amankwah¹, Hycenth Tim Ndah², Johannes Schuler³, Alhasan Lansah Abdulai³, Andrea Knierim²

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

²University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany

³Savanna Research Institute (CSRI-SARI), Ghana

The West Africa sub-region is faced with major interlinked challenges in ensuring sustainable livelihoods in the context of climate change and land degradation. To ensure sustainable food production and resource use, agriculture needs to be resilient through the application of responsive adaptation and coping strategies. While many studies have explored coping and adaptation strategies employed by farmers, little attention has been paid to the farmers' indigenous practices and the role of social cohesion mechanisms.

Using the sustainable livelihood framework, this study addressed this gap by exploring coping strategies and social cohesion mechanisms used by smallholder farmers in northern Ghana. It made use of a mixed-method approach, including a household survey, focus group discussions, expert interviews, field observations, and key informant interviews. Data was collected from 60 households in 6 communities across 3 districts in the study region.

The results showed that social assets such as membership of a self-help group were the most important source of coping, particularly for the most vulnerable households. Such membership enabled farmers to secure micro-loans and receive aid from fellow members during extreme climate events such as floods. Farmers' tacit knowledge emerged as pivotal in coping with climate change and enhancing soil fertility, encompassing traditional weather forecasting, the making of biopesticide, and sustainable land management practices such as ridge and bund creation and intercropping. Key coping practices reported by the study participants included reduction of food consumption, off-farm jobs, selling livestock, charcoal making and reliance on remittances.

The results further revealed that social cohesion plays a key role in helping farmers cope and adapt to climate change while improving soil fertility. Social cohesion is mainly reflected in two different structures depending on gender. While diverse challenges of innovation adoption exist, socio-cultural barriers differ by gender. The study recommends the integration of farmers throughout the innovation development process and propose the need for a concerted effort to strengthen land tenure security policies, ensuring equitable access to farmlands for all genders.

Keywords: Adoption, climate change, social cohesion, sustainable land management

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

Organic manure drive farming system transitions through soil fertility gradients and crop suitability ranges in mid-hills of Himalayan range

Powell Mponela¹, Shova Shrestha², Sagar Kafle¹, Santiago Lopez RIDAURA³, TIMOTHY J. KRUPNIK⁴, SIEG SNAPP³

¹CIMMYT, Nepal ²Nepal Agriculture Research Council (NARC), National Soil Science Research Centre, Nepal ³CIMMYT, Mexico ⁴CIMMYT, Bangladesh

Farmyard manure (FYM)- mixture of animal dung, crop residues, urine, bedding material, fodder residues, household waste and other components - links crop, livestock, and forests to support livelihoods in mid-hills of Nepal. The practice was efficient under low intensity cropping systems for decades but, since 2000s, studies show deficiencies leading to decline in soil quality affecting land suitability for a range of crops. Farmers are aware of soil quality (field fitness), which guides crop choice. As farmers allocate resources towards improving crop and animal production, closing the nutrient cycle through improved utilisation of FYM is the most critical entry point in mixed farming system. Yet, in many parts of mid-hills, existing practices affect manure quality, which range from materials included, composting method, soil quality, landscape suitability, and method of application. FYM preparation and application are labour intensive. Most farmers keep FYM on an open pile or heap, some in an open half heap/pit, and a few in either an open or covered pit. Farmers use doko (approximately 25 kg) to transport to the field when considerable amount is accumulated weeks or months in advance and incorporate during land preparation after rainfall onset. This traditional practice expose manure to sunlight and rain resulting in volatilisation of nitrogen and runoff. Agent-based modelling is used to evaluate farmers' agency decisions to distribute FYM and choice of crops based on resulting soil suitability gradients to steer farms towards sustainable organic pathway. FYM improve soil fertility, soil structure, soil moisture, and tillage operations but to improve crop yields, farmers increasingly apply inorganic fertilisers at the expense of soil quality with significant environmental, economic, and social synergies and trade-offs.

Keywords: Agent-based modelling, farm productivity, farmyard manure, Himalayan Range, resource recovery

Contact Address: Powell Mponela, CIMMYT, Katmandu, Nepal, e-mail: p.mponela@cgiar.org 372 ID 527

Climate-smart grain crops – functionalisation of sorghum milling fractions for application in European cereal-based staple products

LISA CALL¹, RAFAELA SCHEIBELBERGER¹, REGINE SCHÖNLECHNER¹, MARIO JEKLE² ¹BOKU University, Dept. of Food Science and Technology, Austria ²University of Hohenheim, Dept. Plant-based Foods, Germany

As part of a holistic strategy, the potential of climate-smart grain crops - specifically sorghum - is to be identified and subsequently exploited facing the challenge of a sustainable feeding of the growing world population. This is only possible with high-yield and weather-tolerant agricultural raw materials - crops that emit low levels of greenhouse gas while being resilient to heat and drought. Until now, sorghum has not been used as an ingredient in staple foods in Central European countries. However, sorghum shows a high yield and is drought-tolerant. Therefore, bundled research activities and cooperation with industry partners are needed to establish the use of sorghum as a major ingredient in the Western diet and to develop food products of high sensory and nutritional quality. Although sorghum is already used as a staple food in African and Indian regions, its functionality and sensory attributes do not meet the cultural European quality expectations. Unlike wheat, there is still limited understanding of the functional behaviour of different sorghum milling fractions in bakery and pasta products. Thus, it is crucial to investigate the impact of different milling fractions and procedures on technological functionality as well as on nutritional and sensory properties. This will allow the adaption and control of the milling process for producing high-quality sorghum fractions. Furthermore, the functionalisation of grains and milling fractions by several approaches such as germination, enzymatic and hydrothermal processing can improve the functionality in terms of digestibility and gas-holding properties. Evaluating the effects of different pre-processing and processing strategies will enable the production of sorghum-based breads, fine bakery products and pasta of higher nutritional value and sensory acceptability, and thus the implementation of sorghum as a climate-smart grain in the European diet.

Keywords: Bread, environment, functionality, nutrition, pasta, sorghum, sustainability

Contact Address: Lisa Call, BOKU University, Dept. of Food Science and Technology, Muthgasse 18, 1190 Vienna, Austria, e-mail: lisa.call@boku.ac.at

Gendered analysis of climate change adaptation strategies and food security outcomes in selected agroecological zones of Cameroon

Soh Wenda Boris Dinictri, Hamza Moluh Njoya, Arshad Muhammad, Katharina Löhr, Stefan Sieber

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

Climate change remains a major threat to food systems at various scales in the future decades, with serious implications for food and nutrition security, livelihoods, and overall well-being. This makes adaptation, mitigation, and resilience essential for the survival of global populations. Some researchers posit that women have relatively lower adaptive capacity than men while others hold that women are more likely than men to use climate change mitigation and adaptation strategies. Thus, there is no consensus on the adaptive capacity of male relative to female farmers in general and little is known about gender preferences in the adoption of climate change adaptation strategies. However, there is substantial evidence that rural women, particularly, are at high risk of negative impacts from climate change due to increased household responsibilities, agricultural activities, and male outmigration. Hence, given that climate change vulnerability and adaptive capacity tend to vary by gender, identifying and promoting appropriate climate change policies and strategies should consider gender norms. Based on the preceding, this study analyses the gender dynamics in the climate change adaptation practices applied by farmers. We also evaluate the effects of various climate change adaptation practices on food security while accounting for gendered preferences. Data analysis is based on a survey of 768 rural farmers in three agroecological zones of Cameroon conducted in 2023. Descriptive analyses show gender disparities in the choice of climate change adaptation practices. Multiple correspondence analysis and hierarchical clustering are used to establish typologies of farmers based on the climate change adaptation practices applied. Meanwhile, the multinomial logit model is employed to uncover the effect of gender on the choice of typology climate change adaptation practices. Additionally, evaluating food security through household dietary diversity and food insecurity experience scale scores, we employ the Negative Binomial Poisson Regression (NBPR) and Endogenous Switching Poisson Regression (ESPR) models to estimate the effects of climate change adaptation practices on food security. The findings of this study can help shape relevant policy interventions seeking to enhance farmers' adaptation capacity to the changing climate and enhance food security through gender-sensitive climate change adaptation and mitigation initiatives.

Keywords: Climate change, endogenous switching poisson regression Cameroon, gender

Contact Address: Soh Wenda Boris Dinictri, Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries, Rosenstraße 2e, 15374 Müncheberg, Germany, e-mail: borisdinictri.sohwenda@zalf.de

Historical and future winter chill for temperate fruit and nut trees in Afghanistan

Atifullah Shinwari, Lars Caspersen, Katja Schiffers, Eike Luedeling

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

Temperate fruit trees require exposure to chill and heat conditions to overcome the dormant period in winter and resume growth in spring. Rising temperatures due to climate change have already impacted winter chill accumulation in horticulturally vital growing regions worldwide. Afghanistan's intra-regional differences make the country favorable for producing a wide range of fruits and nuts, which constitute approximately 30% of the country's total export earnings. However, expected future temperature increases may be detrimental to the trees' ability to fulfill their chilling requirements. To quantify this risk, we computed and mapped historical and future chill accumulation in Afghanistan. For this purpose, we used long-term daily temperature data from 1980 to 2020 for 51 hydrometeorological stations across the country. Based on the temperature data, we produced four future Shared Socioeconomic Pathway (SSP) scenarios (SSP126, SSP245, SSP370, and SSP585) for five General Circulation Models (GCMs) from the Coupled Model Intercomparison Project Phase 6 (CMIP 6). We used the RMAWGEN weather generator to produce 100 synthetic realisations of weather records for historical (1980, 1990, 2000, 2010, and 2020) and future conditions (2035-2065 and 2070-2100). We quantified winter chill using the Dynamic Model. Additionally, we computed Safe Winter Chill (SWC), which is defined as the level of chill that is expected to be exceeded in 90% of years. We found that SWC has decreased in the low-lying regions mainly in the eastern, southern, and parts of the northern regions, and is projected to further decrease in the future. This reveals a possible future chill risk for high chill-requiring cultivars of different fruit and nut species, including apricot, peach, plum, pistachio and almond, in these regions. In contrast, we recorded an increase in SWC in the northern and central regions, marking these regions as potentially favorable for high-chill species in the future. Our findings support fruit and nut growers in Afghanistan in adapting their orchards to match species' and cultivars' chill requirements with the expected future winter chill.

Keywords: Chill accumulation, chill risk, dormancy, dynamic model, fruit trees, spatial interpolation

Contact Address: Atifullah Shinwari, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Auf dem hügel 6, 53121 Bonn, Germany, e-mail: atif92@uni-bonn.de

From hectares to households: Farmer centric crop-modelling to assess differential climate change impacts and adaptation response

Abel Chemura¹, Paula Romanovska², Roopam Shukla³, Lisa Murken², Christoph Gornott^{4,2}

¹University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, The Netherlands

²Potsdam Institute for Climate Impact Research (PIK), Climate Resilience, Germany

³Indian Institute of Technology, Centre of Excellence in Disaster Mitigation and Management, India

⁴University of Kassel, Fac. of Organic Agricultural Sciences, Germany

Crop simulation models (CSMs) are an important decision support tool in climate risk assessments and in designing resilient agricultural systems. However, the crop models simplify complex farming household diversity and systemic heterogeneities as they consider only the "mean" farmer. In this paper, we are particularly interested to understand how egalitarian is the crop simulation modelling approach in terms of its capacity to provide a more nuanced picture of impacts across different farmer types (classified based on assess and endowment of resources). To do this, we investigated the impact of climate change on maize and sorghum yield, the profitability for different types of farming households through an ex-ante assessment, and the vield response to adaptation strategies (access to irrigation and cropping improved varieties) in Northern Ghana. We find that with the same intensity of changes in climatic variables, yield impacts are different between maize and sorghum, with more impacts on the former across scenarios. We further observe that the highest impacts on maize (16% low emission scenario and 25% for high emission scenario) and sorghum (6% low emission scenario and 14% for high emission scenario) are on the medium resource endowed farmer (MRE), whose yield losses are in order of magnitude of about twice of the low resource endowed farmer (LRE) and the high resource endowed (HRE) farmer. The yield response to adaptation measures was also different across the three farmer types and crops. Irrigation was the most effective adaptation strategy but was more effective for the MRE farmer for maize (52 % low emission scenario and 66% for high emission scenario) and sorghum (74% low emission scenario and 76% for high emission scenario). However, using an improved variety was only effective for maize for the MRE farmer but not so much for sorghum across the farmer types. Our findings underline

Contact Address: Abel Chemura, University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, Enschede, The Netherlands, e-mail: a.chemura@utwente.nl

the critical need to integrate farming household diversity into crop simulation models, to understand the differential impacts of climate change and the prioritised adaptation responses within the same region. These differential impacts and responses should be considered in designing and implementing climate change resilience initiatives.

Keywords: Climate impacts, crop modelling, farmer types, Ghana

Climate change impacts on yield and grain quality: Implications for food security, health and nutrition

David Abigaba¹, Abel Chemura^{2,1}, Bernhard Schauberger^{3,1}, Christoph Gornott^{4,1}

¹Potsdam Inst. for Climate Impact Res., Adaptation in Agric. Systems, Germany

²University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, The Netherlands

³University of Applied Sciences Weihenstephan-Triesdorf, Dept. of Sustainable Agriculture and Energy Systems, Germany

⁴University of Kassel, Fac. of Organic Agricultural Sciences, Germany

Climate change is projected to have significant impacts on agriculture, especially in Africa where crop production is highly sensitive to climate change and extreme weather conditions. However, majority of the current studies on climate change have focused on impacts on yield (grain weight per hectare) and area suitability, while neglecting other important yield components such as the nutritional quality, which are important aspects of food security. The timing of different variables along the development stage of maize is particularly important to the final grain weight and quality. Therefore, the aim of this study was to apply a modelling approach to assess the impacts of climate change on yield and nutritional quality of crops, using maize and West Africa as case studies. The Agricultural Production Systems sIMulator (AP-SIM) model was calibrated and applied to assess climate change effects on maize yield and yield components (particularly protein) in 18 West African countries at 0.5° spatial resolution. In addition, we identify the most relevant climate and environmental variables that affect maize yield and grain quality to aid the design of appropriate mitigation measures. Preliminary results show that the yield and yield components vary both spatially and temporally across the region with some areas and years having higher yields and maize grain characteristics than others. We correlated the maize yields to the grain components to establish the relationships between these across space and time. We also identify the grain characteristics that are most sensitive to weather variability in the region that are at highest risk from climate change and variability. We conclude that it is important to consider other aspects of climate change impacts on crops beyond yield in designing appropriate adaptation strategies and policies towards addressing food and nutritional security across scales.

Keywords: APSIM, climate change, maize, protein, yield

Contact Address: David Abigaba, Potsdam Inst. for Climate Impact Res., Adaptation in Agric. Systems, 14412 Potsdam, Germany, e-mail: dabigaba@pik-potsdam.de

Assessing climate-smart agriculture's impact on food security: The case of semi-arid Tanzania

Mahlet Degefu Awoke¹, Katharina Löhr¹, Anthony Kimaro², Marcos Lana³, Johannes Michael Hafner¹, Stefan Sieber¹

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

²The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF),

Tanzania Country Programme, Tanzania

³Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden

Climate change presents a substantial challenge to global food security, particularly in developing countries like Tanzania, where 78 % of the population relies on agriculture, predominantly rain-fed and subsistence farming. This underscores the necessity for sustainable agricultural practices like Climate-Smart Agriculture (CSA). This study aims to investigate a) the impact of CSA practices on food security among smallholder farming households (HHs) and b) the role of local institutions and indigenous knowledge in facilitating CSA adoption. This study employed a mixed-method approach incorporating 380 HH surveys, 12 focus group discussions, and 15 key informant interviews across six villages in Dodoma region. Seven CSA practices were evaluated, including tree intercropping, intercropping, tied ridges, contour, Chololo pits, manure application, and the use of drought-tolerant improved seeds. Food security was assessed using diverse indicators aligned with the four FAO food security pillars: the Household Food Insecurity Access Scale (HFIAS) (access), the Household Dietary Diversity Score (HDDS) (utilisation), the Coping Strategy Index (CSI) (stability), and food availability was measured in terms of crop production and kilocalories per HH. Preliminary findings indicate that over 90% of HHs adopted intercropping, leading to its exclusion from the food security impact analysis. HHs practicing one or more CSA practices (excluding intercropping) were categorised as CSA adopters. Results show that 42 % of the HH did not adopt any CSA practice, while 58 % adopted one or more practices. Comparing food security between adopters and non-adopters indicates that adopters are more food secure. For instance, 82 % of adopters fell within the most food secure tercile (0–11) according to HFIAS, compared to 61% of non-adopters. Additionally, findings suggest that the role of local institutions is crucial in scaling-up CSA, as more HHs adopted CSA practices in villages with better institutional support. Understanding the impacts of CSA practices on food security among smallholder farming households is crucial to ensuring HH food security; however, identifying effective adoption strategies is equally essential. This research aims to connect food system elements, bridge the gap between theories and practice, inform policy, and empower smallholder farmers to mitigate climate change effects on food security in Tanzania and beyond.

Keywords: Adoption, climate-smart agriculture, food security, smallholder farmers

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

Improving livestock production: Opportunities and challenges for farmers in Central Côte d'Ivoire

Theresa Ebert¹, Ange N'Goran², Sala Alanda Lamega¹, Johannes Isselstein¹, Ariane Amin³, Faustin Parfait Koutouan⁴

¹Georg-August University Göttingen, Dept. of Crop Sciences, Grassland Science, Germany ²Cheikh Anta Diop University Dakar (UCAD), Senegal

³*Félix* Houphouët-Boigny University, Swiss Center for Scientific Research, Côte d'Ivoire ⁴*National Polytechnic Inst. Félix Houphouët-Boigny (INP-FHB), Côte d'Ivoire*

Climate variability and a constant population rise are among the factors that negatively influence livestock production in West Africa. Particularly in Côte d'Ivoire, these factors contribute to important disparities between livestock production and demand. To meet the demand for livestock products (e.g. beef), the country relies heavily on importation. In order to decrease the dependency on imports while meeting the increasing demands for livestockbased protein, an inland increase in production is necessary. However, a first entry point in developing and promoting sustainable production mechanisms will require the evaluation of existing production systems.

Therefore, this study aims to assess the opportunities and challenges for farmers of cattle production in Central Côte d'Ivoire with a special focus on the effects of climate change. To achieve this, a comprehensive survey across 120 farms in two different climatic areas was conducted in Côte d'Ivoire. The two regions involved are Toumodi which is located in the district Lacs and Bouaké which is located in the district Vallée du Bandama.

The main objectives of the present investigation are (i) to understand the current production systems of beef cattle and (ii) to evaluate the perceptions of livestock farmers concerning the current impacts of climate change on production. In addition, this study aims (iii) to identify the adaptation strategies for beef cattle production systems which are currently used, as well as, to explore farmers knowledge about innovative climate-resilient adaptation strategies. The results of the study are intended to help promote livestock production to attain self-sufficiency in Côte d'Ivoire with a broader implication for the Coastal countries in West Africa.

Keywords: Adaptation strategies, cattle, climate change perception, smallholder

Contact Address: Theresa Ebert, Georg-August University Göttingen, Dept. of Crop Sciences, Grassland Science, Von-Siebold-Straße 8, 37075 Göttingen, Germany, e-mail: theresa.ebert@stud.uni-goettingen.de

Farmers' adaptation strategies for coping with cyclone effects in Zimbabwe

WILLIAM NKOMOKI, DAVID MURATA, SAFIYYA KASSIM Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences; Dept. of Economics and Development, Czech Republic

The recurrence of cyclones is a significant concern within sub-Saharan Africa, particularly along the Zimbabwe-Mozambican belt. The region is highly susceptible to the adverse effects of climate change, and experiences increased frequency and intensity of cyclones, including cyclone Eloise (2021), Idai (2019), Japhet (2003), and Eline (2000). This decreases agricultural productivity, food security, and livelihood, especially for vulnerable agrarian-dependent smallholder farmers. The study investigated the adoption of sustainable practices, the factors influencing the adoption, and the sources of information for early warming. Data were collected from in-depth expert interviews and survey questionnaires through face-to-face interviews with 150 respondents in Eastern Zimbabwe. The study employed a multi-stage sampling design, including a purposive selection of regions experiencing recurring cyclones. The findings revealed that planting vetiver grass and stone terracing are the most adopted measures, with 78.49% and 74.19%. Agroforestry and planting trees as windbreaks account for 55.91 % and 54.84 %, respectively. The multivariate regression model indicates that age, gender, access to credit, labour endowment, membership of cooperatives, farming experience, farm size, farm locations, land tenure security, and access to extension services positively contribute to adopting climate-smart practices. The major sources of information for early warning climatic systems dissemination to the farmers were cell phones (messaging), radio, and village community meetings, with 96.19%, 87.62 %, and 53.3 %. Understanding adaptation strategies is crucial for enhancing resilience and reducing vulnerability to cyclone effects. Therefore, policymakers must prioritise and promote adopting local adaptation practices widely acceptable to the farmers. Further, consideration of the timely dissemination of information to the farmers and follow-ups is imperative for planning and investment.

Keywords: Adaptation, climate change, cyclones, information, resilience, smallholder, sustainable practices

Contact Address: William Nkomoki, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences; Dept. of Economics and Development, Kamycká 129, 165 00 Prague, Czech Republic, e-mail: nkomoki@ftz.czu.cz

Role of social networks in coping with climate change-induced shocks in eastern Ethiopia

Fuad Shuker¹, Wesagn Berhane², Hakim Sadik², Andreas Thiel³

¹*University of Kassel, Sustainable International Agriculture (SIA), Germany*

²*Haramaya University, Rural Development and Agricultural Innovation, Ethiopia*

³University of Kassel, International Agricultural Policy and Environmental Governance, Germany

Ethiopia has been experiencing climatic shocks such as droughts and floods, increased temperatures, and erratic rainfall. The need for urgent and effective steps to build resilience is unquestionable. To respond to and recover from climate-induced shocks, socio-cultural networks are conventional approaches that promote collective action and mutual support of various communities. As a matter of fact, the crucial roles of social networks in the resilience of communities faced with climatic-induced shocks in rural areas are still underresearched and under-conceptualised, particularly in our country. This study aimed to assess the roles of social networks in coping with climate changeinduced shocks in Fedis districts, Eastern Hararghe zones of Ethiopia. The study employed a mixed research approach along with a cross-sectional study design. Data were collected from 210 HHs and analysed through descriptive statistics while qualitative data were analysed through thematic analysis. The study findings found that various climatic shocks such as droughts, erratic rainfall, human-wildlife conflict, crop failure, locust invasion, animals dead due to lack of water and postures, wind, water resources-based conflict, and floods were experienced by the community over the last five years. To respond to these shocks kin-based support, Faraka, non-kin/non-tribe networks, Hafarfata, Guza labour sharing, NGOs/PSNP, Mandara, gender-based groups, Gumata, religious-based support, and government organisation were among the social networks that were playing a significant role in coping with climate-induced shocks. But when a climatic shock is covariate and lasts longer, the social-network-based coping strategies often fail. To solve these climatic shocks sustainably from the bottleneck, both social capital practise and nature-based mitigation should be taken together.

Keywords: Climate-induced shocks, coping capacity, eastern Ethiopia, social network

Contact Address: Fuad Shuker, University of Kassel, Sustainable International Agriculture (SIA), 37213 Witzenhausen, Germany, e-mail: fuadee04@gmail.com

Stakeholder engagement in agro-climate service planning

Thi Thu Giang Luu¹, Eike Luedeling¹, Cory Whitney¹, Lisa Biber-Freudenberger²

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

²University of Bonn, Center for Development Research (ZEF), Germany

The impacts of weather, climate variability and climate change on agricultural production underline the increasing importance of actionable agro-climatic services for improving the resilience of small-holder farmers. While, in general, the provision of climate services has increased, there is often a mismatch between service providers and users about what constitutes useful information. Transitioning from supply-driven provision of climate and agricultural information to demand-driven agro-climate services (ACS) at scale cannot be accomplished in a top-down manner but requires the engagement of diverse stakeholders in all phases of ACS, including the designing and budgeting phases. However, such pre-stage transitions often feature uncertainty, scattered knowledge, conflicts of different views, and the challenge of bringing stakeholders to the same table.

Our study offers a transparent and systematic method to address critical challenges in the early stages of ACS development by engaging stakeholders in generating and translating system knowledge for decision-making. Our findings reveal that considering multiple stakeholder attributes – such as availability, experience, gender, expertise, cost and benefit profile, interest, influence, relevance, and attitude – is critical for effective stakeholder engagement. Combining these attributes with stakeholders' system knowledge and understanding of the decision-making process, in a case study in Dien Bien, Vietnam, we identified when, where, and how stakeholders could engage in the socio-economic development planning process. For example, stakeholders with extensive experience and relevant expertise should focus on producing evidence about the needs and impacts of ACS and include it in formal reports to encourage political interest. Influential stakeholders with an interest in and relevance to ACS should be involved in key decision-making moments within the policy cycle. If interest among influential stakeholders is limited, a preparatory process that provides credible, legitimate, and relevant evidence is recommended. Throughout the stakeholder engagement process, we emphasised the need for a coordinating body that is viewed as relevant to decision-making yet has minimal conflicts of interest.

Our proposed engagement approach guides the development of ACS that is responsive to local needs for climate change response. Our methods can be applied to support other complex decision-making processes.

Keywords: Complexity, decision analysis, stakeholder attributes, uncertainty, upscaling

Contact Address: Thi Thu Giang Luu, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Auf dem hügel 6, Bonn, Germany, e-mail: tluu2@uni-bonn.de

Using digital tools to enter new adaptation domains in cocoa and coffee climate adaptation planning

Paul Günter Schmidt¹, Christian Bunn²

¹*The Alliance of Bioversity International & CIAT, Climate Action, Spain* ²*The Alliance of Bioversity International & CIAT, Climate Action, Colombia*

Climate change threatens the viability of smallholder cocoa and coffee farming globally, with shifting agro-climatic zones and crop-specific hazards posing significant challenges. Current climate adaptation efforts prioritise broad practices like agroforestry and regenerative agriculture. Leveraging climate projection data for targeted adaptation is seen as complex and seldomly used. Adaptation domains categorise areas by incremental, systemic, and transformational adaptation needs, offering strategic guidance, yet operationalizing them remains challenging. We developed a digital tool, ACLIMATAR, utilising human-centered design (HCD) principles to facilitate structured discussions and offer targeted adaptation planning support. Drawing on local knowledge and expert workshops, we compiled sets of climate adaptation practices tailored to specific hazards and adaptation domains, bridging climate projection data with agronomic advice. Our review spans major cocoa and coffee producing regions in Latin America and East and West Africa. Our study underscores core farm system enhancements crucial for effective climate adaptation, including ground cover, shade levels, pruning, soil quality enhancement, and water management, as well as post-harvest techniques. ACLIMATAR proofed to transcends typical timescales in extension work, facilitating long-term planning. While adaptation domains offer useful planning frameworks, differentiated adaptation action is needed across regions. Incremental adaptation regions may suffice with Good Agricultural Practices and hazard mitigation, whereas systemic adaptation regions require deeper understanding, possibly benefiting from climate analogues. Transformational adaptation regions demand integration with viable livelihood options and realistic business planning. Our findings underscore the vital role of structured frameworks like HCD and digital tools in fostering climate adaptation discussions, challenging conventional approaches. By integrating risk analysis with adaptation planning, our approach provides a structured framework for action, empowering stakeholders to navigate climate change complexities and bolster resilience in cocoa and coffee smallholder farming communities.

Keywords: Climate change, decision support tools, digital tools

Contact Address: Paul Günter Schmidt, The Alliance of Bioversity International & CIAT, Climate Action, Calle monasterio de urdax 23 piso 7b, 31011 Pamplona, Spain, e-mail: p.schmidt@cgiar.org

Biosphere learning laboratory Lake Bosomtwe: Biosphere reserve management in times of climate change

Franziska Rottig¹, Tobias Cremer¹, Yaw Boakye Agyeman², Kwame Nkrumah Hope³, Emmanuel Danquah⁴, Emmanuel Opuni-Frimpong⁵

¹Eberswalde University for Sustainable Development, Department for Forest Utilization and Timber Markets, Germany

²University of Energy and Natural Resources Sunyani, Dept. of Ecotourism, Recreation and Hospitality, Ghana

³AAMUSTED, College of Agriculture Education, Ghana

⁴KNUST, Fac. of Renewable Natural Resources, Ghana

⁵CSIR-Forestry Research Institute of Ghana, Ghana

Lake Bosomtwe Biosphere Reserve (BR) is one of three UNESCO BR in Ghana located in the Ashanti Region and provides livelihood for about 70,000 people in 30 communities. Being the most recent BR of Ghana, the reserve hasn't been included in regional and national planning for future development, and the local and regional population is hardly aware of the status as a biosphere reserve and the related regularities.

The BR has been facing ever more challenges regarding carrying capacity, overuse of fish resources and increased extraction of forest stock leading to an overexploitation and degradation of the vulnerable ecosystem of the BR. Moreover, climate change increases the vulnerability of the ecosystem and local population.

The 'Biosphere Learning Laboratory Lake Bosomtwe', funded by DAAD, as an academic partnership among three Ghanaian universities and the University of Sustainable Development in Eberswalde (Germany) elaborates needs and demands for research and transfer in the BR, to foster a sustainable development of the BR and its natural resources as well as to improve the quality of life for all individuals and communities.

Based on comprehensive desktop research as well as consultations and workshops with all partner institutions and local inhabitants, a research outline with seven priority research and transfer subjects was elaborated, which touched upon the overarching topics of agroecology and sustainable resource management practices, sustainable water and fisheries management as well as forestry, environmental conservation and ecosystem services. The identified research needs were taken up in field work by six students from the University for Sustainable Development Eberswalde tackling topics such as "Participation of women in tourism", "Construction of floating sewage treatment

Contact Address: Franziska Rottig, Eberswalde University for Sustainable Development, Department for Forest Utilization and Timber Markets, Schicklerstr. 5, 16225 Eberswalde, Germany, e-mail: franziska.rottig@hnee.de

plants", "Linking cultural heritage and environmental protection", "Fisheries management" and "Combining cocoa cultivation with agroforestry utilisation".

The research outcomes are of great interest for academia, the public institutions and local population aiming at the preservation of the vulnerable ecosystem of the BR Lake Bosomtwe. Based on the results of the project, systematic and well-structured research activities can be implemented to support the local population in the biosphere reserve, facing severe challenges in times of climate change.

Keywords: Alternative livelihood, biosphere reserve, stakeholder participation, sustainable landuse management

Crop management practices and coping strategies of rice farmers in typhoon prone Eastern Visayas, Philippines

LUZ ASIO¹, MARVIN CASCANTE², MA. VICTORIA ASIO³ ¹Visayas State University, Dept. of Agronomy, Philippines ²National Taiwan University, Dept. of Agricultural Chemistry, Taiwan ³James Cook University, College of Science and Engineering, Australia

The Philippines ranks among the world's most typhoon-affected regions, with climate change intensifying their frequency and strength. Over recent decades, typhoon occurrences have surged from 15 to 20 annually, particularly impacting Samar and Leyte islands in the Eastern Visayas region. The super typhoon Haiyan on November 07, 2013, ravaged the region and caused unprecedented losses to crops, properties, and lives. In the present study, we surveyed 40 lowland rice farmers in Borongan, San Julian, and Dolores, Eastern Samar, to assess the impact of climate change on farming practices and identify coping mechanisms.

While farmers exhibit resilience towards recurrent typhoons and floods, their primary concerns revolve around the scarcity of seeds, fertilisers, and reliable irrigation systems, exacerbated by changing rainfall patterns. Rising temperatures, erratic rainfall, and dwindling water resources pose significant challenges to agricultural productivity. In response, farmers adjust planting calendars based on rainfall and soil moisture availability, resort to chemical fertilisers to alleviate declining soil fertility and use pesticides to control increased pest and disease occurrences. In some cases, rice farmers switch to sweet potato cultivation to adapt to limited soil moisture and the occurrence of strong typhoons. Farmers have observed that sweet potatoes can tolerate strong typhoons, as they experienced during Typhoon Haiyan.

This study implies the critical need for adaptive strategies to address the complex challenges posed by climate change and safeguard the livelihoods of Filipino rice farmers in the face of escalating climate risks. Moreover, the findings can help the local government formulate policies that would help farmers improve their rice production in a changing climate.

Keywords: Climate change, rainfed rice production system, typhoon-prone agroecosystem

Contact Address: Luz Asio, Visayas State University, Dept. of Agronomy, College of Agriculture and Food Science, 6521 Baybay City, Philippines, e-mail: luz.asio@vsu.edu.ph

Modelling of the climate change impacts on the Iranian riverine fish species diversity as a hot spot area

Hossein Mostafavi¹, Toktam Makki¹, Ali Akbar Matkan², Roozbeh Valavi³, Robert Hughes⁴, Azad Teimori⁵, Houman Liaghati¹, Stefan Schmutz⁶

¹Shahid Beheshti University, Environmental Sciences Research Institute, Dept. of Biodiversity and Ecosystem Management, Iran

²Shahid Beheshti University, The Center for Remote Sensing and Geographic Information System Research, Iran

³CSIRO Environment, Australia

⁴Oregon State Univ., Dept. of Fisheries, Wildlife, and Conservation Sci., United States ⁵Shahid Bahonar University of Kerman, Dept. of Biology, Iran

⁶BOKU University, Austria

Iran is one of the world's biodiversity hot-spots. However, most of riverine fish species in this country are currently under threat from numerous human activities. In this context, climate change acts as an additional threat compromising biodiversity and freshwater ecosystem function and potentially disturbing the ecological services they provide. In this study, we predicted potential relative probability of 132 fish species under two climate change scenarios (RCP 4.5 and RCP 8.5) in river habitats of Iran in the 2050s and the 2080s by MaxEnt model. Seven environmental variables (maximum width, elevation, river slope, the basins occupied by the target species, average annual precipitation, annual mean temperature, and the temperature difference between the coldest and hottest months of the year) were used for modelling. Also, AUC (Area Under the Curve) index was used to evaluate the modelling performance.

The results of this study showed that under optimistic (RCP 4.5) and pessimistic (RCP 8.5) scenarios in the 2050s and the 2080s, species will show different outcomes to their habitat range such as "reduction", "expansion", "reduction and expansion", as well as "no change". Thus, 37 species had a "reduction" response in all scenarios. 14 species had only "expansion" reaction, 58 species had "reduction and expansion", 6 species had "no change" and 17 species had a combination of reactions in the scenarios. Comparing themaps of estimating the species richness in different climatic scenarios with the current condition and observing the difference in the presence of species, we found that the greatest decrease in species richness is predicted under the RCP 8.5 scenario in 2080 in the Caspian Basin, especially its western regions.

With the warming climate, the distribution range of some species in the country will expand, some will be limited and some will probably remain constant. In other words, the country's biodiversity will certainly change. Therefore, this study will provide valuable information to managers and decision makers to prevent possible damage by taking appropriate measures and prioritisation.

Keywords: Biodiversity conservation, climate heating impacts, Iran, MaxEnt

Contact Address: Hossein Mostafavi, Shahid Beheshti University, Environmental Sciences Research Institute, Dept. of Biodiversity and Ecosystem Management, Tehran, Iran, e-mail: hmostafaviw@gmail.com

Greenhouse gases in livestock farming: The case study in Fleckvieh cattle in the Peruvian Amazon

Deysi Yenny Ruiz Llontop¹, Segundo M. Portocarrero-Villegas¹, Hugo Frias¹, Luis Murga¹, Joe Mantilla Oliva², Dante Pizarro Paz³, José Velarde-Guillén⁴, José Américo Saucedo-Uriarte¹

¹Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Instituto de Investigación en Ganadería y Biotecnología, Peru

²GENEX CDP PERU, Cajamarca, Peru

³University of Wisconsin-Madison, Dept. of Animal & Dairy Sciences, United States ⁴Universidad Nacional Agraria La Molina, Facultad de Zootecnia, Peru

Small-scale production of milk and beef is crucial for the economy and food security. However, mitigating the environmental impact of livestock farming requires the implementation of sustainable practices. The carbon footprint (CF) framework, which estimates all greenhouse gas (GHG) emissions throughout a product or service's life cycle, serves as a crucial tool in this regard. This study aimed to quantify the GHG in ten Fleckvieh production systems distributed in four provinces of the Peruvian Amazon region: Chachapoyas (System I; n = 2), Bongara (System II; n = 4), Rodriguez de Mendoza (System III; n = 2), and Utcubamba (System IV; n = 2). Parameters such as average live weight, number of animal units (AU), dry matter intake, fat and proteincorrected milk (FPCM), digestibility, and protein content of forage consumed were evaluated. The CF was calculated based on the methodologies recommended by the Intergovernmental Panel on Climate Change (2019). The CF (CO² eq kg⁻¹ of FPCM), enteric methane, methane from manure, and manure nitrous oxide were analysed and compared using Duncan's Multiple Range Test across systems. Pearson's correlation coefficient was then calculated to assess the strength and direction of the relationships. Results revealed a CF range of 1.72 and 2.53 kg CO^2 eq kg⁻¹ of FPCM, depending on the global warming potential and the allocation method (economic and biophysical). Enteric methane (90.8%) was the main contributor to GHG emissions, followed by nitrous oxide from manure management (6.9%). Positive correlations were found between methane emissions with total FPCM (r = 0.94), AU (r = 0.99), lactating cows (r= 0.95), and low-producing animals (r = 0.97). System I (67.7 kg CH_4 /kg of FPCM) exhibited the lowest enteric methane emissions, suggesting better livestock and feed management than Systems II (93.6 kg CH_4/kg of FPCM) and IV (89.1 kg CH_4/kg of FPCM). Our study highlights the need to optimise herd composition, increase production levels and decrease low-producing animals to reduce the CF. Likewise, improving the forage nutritive value can increase milk production, securing the economic well-being of smallholder farmers and the sustainability of the farming sector in the Peruvian Amazon.

Keywords: Climate change, life cycle assessment, livestock, methane, nitrous oxide

Contact Address: Deysi Yenny Ruiz Llontop, Universidad Nacional Toribio Rodríguez de Mendoza de Amazonas, Instituto de Investigación en Ganadería y Biotecnología, Jr. Triunfo Cuadra 2, 01001 Chachapoyas, Amazonas, Peru, e-mail: yennyruiz2211@gmail.com

Identification of potential future areas for sustainable cashew production in Togo using the maxent model

Kossi-Messan Jacques Agboka 1,3 , Dodiomon Soro 2 , Komi Agboka 3

¹Félix Houphouët-Boigny University, WASCAL-Graduate Research Program on Climate Change and Biodiversity, Côte d'Ivoire

²Félix Houphouët-Boigny University, Lab. des Milieux Naturels et Conservation de la Biodiversité-UFR Biosciences-UFHB, Côte d'Ivoire

³Université de Lomé, Ecole Supérieure d'Agronomie (ESA), Togo

Understanding current and future potential habitats is crucial for designing sustainable management policies and cashew-growing practices that are more resilient to climate change. This study assessed the current distribution and predicted the potential effect of climate change on the habitat distribution of Anacardium occidentale L. in Togo under two global circulation models (Had-GEM3-GC3.1-L and MIROC6) and two shared socio-economic pathways (SSP-245 and SSP585) by 2050. The maximum entropy algorithm, 2538 species occurrence records and a combination of seventeen (17) climate and soil variables were used. The results showed that soil, followed respectively by the annual precipitation (bio12), and the temperature seasonality (bio4), are the most significant environmental factors affecting cashew distribution in Togo. Based on the current model, 78.92% of the Togolese landscape is highly favourable to sustainable cashew-growing practices. In 2050, according to the MOROC6 Model, sustainable cashew nut production areas will be reduced to 5.24% under the SSP 245 scenario and completely disappear under the SSP585 scenario. However, for the HadGEM3-GC3.1-L model in 2050, the areas of sustainable cashew nut production in Togo will be reduced to 3.71 % and 0.26 % respectively for the SSP245 and 585 scenarios. In short, the results of this study, which was carried out for the first time in Togo, point out the need to put in place a strategy for the conservation and sustainable cultivation of cashew trees in Togo. This research will help to produce more cashew nuts and contribute to achieving sustainable development objectives. This study will also help the cashew nut production sector to become climate resilient.

Keywords: *Anacardium occidentale* L., climate change, ecological niche modelling, sustainable agriculture

Contact Address: Kossi-Messan Jacques Agboka, Félix Houphouët-Boigny University, WASCAL-Graduate Research Program on Climate Change and Biodiversity, Abidjan, Côte d'Ivoire, e-mail: agboka.j@edu.wascal.org

Fertiliser management effect on rice growth and CH₄ emissions in lowland paddy rice in Madagascar

Lalaina Andrianarijaona¹, Andry Andriamananjara¹, Tantely Razafimbelo¹, Manoa Arifetra Raminoarison¹, Michel Rabenarivo¹, Yasuhiro Tsujimoto², Aung Zaw Oo²

¹*University of Antananarivo, Lab. des Radioisotopes, Madagascar*

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

Rice fields are a major source of CH_4 emissions, a potent greenhouse gas responsible for 0.6°C of global warming. Recent rice intensification and expansion in Africa have contributed to the rise in CH_4 emissions, which account for 7 % of global emissions. In Madagascar, rice is a staple food and the third largest rice producer in Africa. However, rice production is still limited in fulfiling the entire population's needs due to low soil nutrient availability. Conventional organic amendments and mineral fertilisers can enhance soil nutrients and rice growth. However, fertiliser management can stimulate CH_4 production by providing a carbon source for the CH_4 -producing bacteria. The potential CH_4 emissions from fertiliser management in a tropical context are not well known. To assess the effect of fertiliser management on CH_4 emissions and rice production, a pot experiment with farmyard manure (FYM: 10 t ha^{-1}), Pbroadcasting (60 kg P ha^{-1}), and control (no fertiliser), and a field experiment with FYM (10 t ha⁻¹) and N:P:K (45:45:45 kg ha⁻¹) were conducted. In the pot experiment, low rice growth under control resulted in low rice yield and CH_4 emissions. Meanwhile, FYM and mineral fertiliser significantly increased CH_4 emissions by 84.8 % and 71%, respectively, compared to the control. Compared to FYM, mineral fertiliser reduced CH₄ emissions by 7.47% while increasing grain yield two fold. Field experiments further confirmed that mineral fertiliser had lower CH₄ emissions (133.4 kg ha^{-1}) than FYM (185.3 kg ha^{-1}). However, rice yield increase by mineral fertiliser over FYM was minimal (0.27 t ha^{-1}) and not significant. In both experiments, high CH_4 emissions under FYM would mainly be attributed to the high carbon input into the flooded rice fields, which is a major carbon substrate for methanogenic bacteria in CH_4 production. The results also showed that mineral fertiliser significantly reduced greenhouse gas intensity (CH₄ emissions per unit grain yield) compared to FYM due to low CH_4 emissions while improving rice yield. In conclusion, mineral fertiliser application decreased CH₄ emissions while increasing rice productivity, illustrating its environmental and agronomic potential in climate change mitigation and food security.

Keywords: Fertiliser management, greenhouse gas intensity, methane, nutrient deficient soils, rice yield

Contact Address: Lalaina Andrianarijaona, University of Antananarivo, Lab. des Radioisotopes, Lot iie 8bis ae Ambohimirary Route d'Andraisoro, Antananarivo, Madagascar, e-mail: lalaina.andrianarijaona@gmail.com

Adaptation of crop portfolios to perceived indicators of climate variability by smallholder farmers in south-western Uganda

Dina Nabasumba^{1,2}, Grace Kagoro², Hakim Bukenya², Ronald Twongyirwe³, Julius Lejju², Justine Nakintu², Raphael Wangalwa², John Sekajugo⁴, Robert Muzira⁵, Immaculate Nakazibwe², Liesbet Vranken⁶, Matthieu Keryvn¹

¹Vrije Universiteit Brussels, Dept. of Geography, Belgium

²Mbarara University of Science and Technology, Dept. of Biology, Uganda

- ³*Mbarara University of Science and Technology, Dept. of Environment and Livelihoods Support Systems, Uganda*
- ⁴Mountains of the Moon University, Dept. of Environmental and Natural Resources, Uganda
- ⁵Mbarara Zonal Agricultural Research and Development Institute, Crop and Natural Resources Research Program, Uganda
- ⁶KU Leuven, Division of Bioeconomics, Dept. of Earth and Environmental Sciences, Belgium

Smallholder farmers in sub-Saharan Africa (SSA) rely mainly on rain-fed agriculture, which is vulnerable to climate variation. This calls for adaptation of production systems and practices to climatic variations to secure household food, nutrition and income security. Variations in seasonal rainfall in terms of amount, timing, consistency, and seasonal temperature changes, have often caused crop failures, reduced crop productivity or reduced areas suitable for growing certain crops in SSA. Several studies have documented how climate variability has affected crop productivity especially yield in agricultural production systems in SSA. However, there is limited information on how smallholder farmers in SSA select their crops and varieties as a coping mechanism to climate variability. Using south-western Uganda as a case study area, this study investigates whether smallholder farmers' perception of climate variability influences their crop choices. Through probability sampling procedures, a household survey was conducted with 583 smallholder farmers in three districts in south-western Uganda, between January and March, 2024. The survey was complemented with 21 key informant interviews. Data were collected on demographic and socio-economic profiles of households, smallholder farmers' opinions about variations in rainfall and temperature variables in the past 12 months and the trend in the past 10 years. Crop types and varieties selected or abandoned by smallholder farmers and the reasons for adoption or abandonment were explored. In this contribution, we will report on the preliminary results of the analysis of the survey dataset, highlighting how crop choices of smallholder farmers are influenced by their perception of climate variability.

Keywords: Smallholder farmers, crop choices, perception, rainfall variability

Contact Address: Dina Nabasumba, Vrije Universiteit Brussels, Dept. of Geography, Brussels, Belgium, e-mail: dina.nabasumba@vub.be

Impact of climate change on oceanic ecosystems: Challenges, adaptations and strategies

Karolina Łachmacka

Wroclaw University of Environmental and Life Sciences (UPWR), Dept. of Applied Economics, Poland

Climate change is an undeniable reality that is exerting an increasingly significant impact on our planet. The rise in average atmospheric temperatures, changes in rainfall patterns, melting glaciers, and rising sea levels are just some of the events resulting from these changes. One of the areas particularly affected by these consequences is oceanic ecosystems. The ocean, the heart of life on Earth, is becoming increasingly vulnerable to the effects of climate change.

In this study, we conduct a comprehensive analysis of the impact of climate change on oceanic ecosystems. We focus on identifying the threats posed by these changes to marine life and to people who depend on seas and oceans as a source of food, livelihoods, and life itself.

We also analyse various adaptive and mitigative strategies that can be implemented to minimise the negative effects of climate change on oceanic ecosystems. These strategies include actions at the local, national, and global levels, such as reducing greenhouse gas emissions, protecting marine areas, and promoting sustainable management of marine resources.

The research methodology utilised in this study involved the utilisation of secondary data. Data collection was facilitated through the employment of the documentary method alongside an extensive review of specialised literature within the field. The gathered data were meticulously analysed employing both descriptive and comparative methodologies. Subsequently, the findings were articulated and presented in both textual and graphical formats, enhancing the comprehensibility and visual representation of the results. The graphical elements were meticulously crafted using ProCreate software, providing an aesthetically pleasing and informative supplement to the textual analysis.

Keywords: Adaptation strategies, climate change, marine life, mitigation strategies, ocean protection, oceanic ecosystems

Contact Address: Karolina Łachmacka, Wroclaw University of Environmental and Life Sciences (UPWR), Dept. of Applied Economics, Norwida 25, 58-375 Wrocław, Poland, e-mail: 122048@student.upwr.edu.pl

How does social capital promote adaptive behaviour among Iranian farmers?

 $\begin{array}{l} Masoud \ Yazdan panah^1, \ Tahereh \ Zobeidi^2, \ Kevan \ Lamm^3, \ Alexa \ Lamm^3, \\ Katharina \ L\"{Ohr}^4, \ Kyle \ Woosnam^3 \end{array}$

¹Agricultural Sciences and Natural Resources University of Khuzestan, Iran

²International Institute for Applied Systems Analysis (IIASA), Cooperation and Transformative Group, Austria

³University of Georgia, ALEC, United States

⁴Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

Climate change is a global challenge among humans and their socio-economic activities, health, livelihood, and food security, and is the most serious threat to agricultural productivity. Adaptation to climate change and its effects is a complementary response to reducing vulnerability in particular agriculturebased economies. Adaptation measures are urgently needed to reduce adverse consequences of climate change on ecosystems and food systems. Social capital has provided a new outlook to examine the variances in individuals' abilities to adapt to climate variability. Nevertheless, the fundamental role of social capital in adapting to climate variability in agriculture has not been entirely discovered. Consequently, the current study considers how social networks, norms, participation, trust, and solidarity (as aspects of social capital) may explain climate change adaptive behaviour among Iranian farmers. Survey data (employing a questionnaire) were collected from 250 farmers randomly selected in Susangerd city, within Khuzestan, Iran. An integrated model combining social capital, beliefs on climate change, and risk perceptions are used. Results of structural equation modelling show that the proposed integrated model explained 69% of the variance in adaptation behaviour and 66% and 40% of the variances in risk perception and climate beliefs. Such results demonstrate the robustness of the model in predicting adaptation strategies. Based on the findings, social solidarity and climate beliefs were the most effective predictors of risk perception, while farmers' social networks were the most important predictors of behaviour. This study, by confirming the importance of social capital on the farmers' beliefs, risk understanding, and adaptation behaviour, offers suggestions for fostering and implementing more practical adaptation strategies.

Keywords: Adaptation strategies, climate change, participation, social solidarity

Contact Address: Masoud Yazdanpanah, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, 744581 Ahvaz, Iran, e-mail: masoudyazdan@gmail.com

Field to landscape experiments: practices and technologies

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Towards high throughput system in detecting GHG emissions in rice production: Assessment of measurement approaches

THI BACH THUONG VO¹, REINER WASSMANN², RYAN ROMASANTA¹, CAESAR ARLOO CENTENO¹, MARY LOUISE MENDOZA¹, ANDO M. RADANIELSON¹ ¹International Rice Research Institute (IRRI), Dept. of Sustainable Impact through Rice-Based Systems (SIRS), Philippines ²Karlsruhe Institute of Technology, Germany

Since flooded rice fields are a major source of greenhouse gas (GHG) methane (CH_4) and to a lesser extent nitrous oxide (N_2O) . Several Asian countries focus on rice production for mitigating GHG emissions in the agricultural sector. In turn, it is imperative to accurately quantify emissions of CH_4 and N₂O at field level as the basis for scaling up. Accessibility to appropriate field technologies becomes a prerequisite for reliable quantifications of (i) countries' commitments to international agreements like the UN Framework Convention on Climate Change as well as (ii) the emerging national and international carbon markets. The commonly applied method of closed chamber technique based on manual sampling entails significant restrictions in terms of observation sites and periods, particularly for regions lacking analytical lab facilities. At the other end of the technological scale, Eddy Covariance measurements facilitate accurate flux records, but require high investment costs and are unsuitable for comparative measurements of agronomic practices. In this study, we assess the pros and cons of a fast in situ measurement approach using the laser-based system trace gas analyzer with high accuracy and immediate detection of CH₄ and N₂O fluxes in the field. In combination with an automatically controlled system for sample transfer, this cutting-edge approach facilitates enhanced efficiency and mobility. The full potential of this technology, however, can only be tapped with advanced procedures for database management. Focusing on a case study in a research station at IRRI, our assessment highlights its potential for advancing understanding of main mechanisms of GHG emissions in rice systems with access to high resolution in space and in time of emissions data that were not possible before to inform mitigation strategies. We elaborate as well on the pivotal role of research in ensuring the exploitation of different technological progress for accessibility of on farm measurements.

Keywords: Advanced technology, field measurement, rice GHG

Contact Address: Thi Bach Thuong Vo, International Rice Research Institute (IRRI), Dept. of Sustainable Impact through Rice-Based Systems (SIRS), 4031 Los Baños, Philippines, e-mail: t.vo@irri.org

Cattle farming, armed conflict, and climate change: Possibilities and limitations in a case study in the Colombian Amazon

Verenice Sánchez Castillo¹, Paula Daniela Orduz Ramos², Mateo Pazos Cárdenas³, Natalia Triana-Angel³

¹Universidad de la Amazonía, Fac. de Ingenería, Colombia ²Wageningen University & Research, Intern. Development Studies, The Netherlands ³The Alliance of Bioversity International & CIAT, Tropical Forages Program, Colombia

The Colombian armed conflict has long impacted both the population and the country's productive systems. However, the signing of the Peace Agreement between the Colombian State and the FARC-EP in 2016 has introduced new possibilities. While violence persists, particularly involving other armed actors connected to drug trafficking, there has been a push for productive projects supported by the State and international cooperation. These initiatives aim to enhance agricultural and livestock value chains in rural areas affected by the conflict, such as the Colombian Amazon. Our study delves into the dynamics of armed conflict and its impact on dairy farmers and milk production and explores perceptions of climate change and the adoption of sustainable technologies for mitigation and adaptation in the municipality of Puerto Rico (in the Caquetá department of the Colombian Amazon region, one of the most severely affected areas not only by violence but also by deforestation). Using qualitative methods including workshops, focus groups, and key informant interviews with 32 cattle farming families, we found that traditional cattle systems in the region leave small producers particularly vulnerable to extreme weather events, with limited access to adaptation strategies. Their ability to adapt depends on the availability of various forms of natural, physical, and social capital. Recognizing climate change adaptation as a multifaceted issue is crucial and requires the incorporation of this understanding into the development of tailored strategies, technologies, and practices that consider the needs, contexts, and perspectives of affected populations. Additionally, understanding how conflict has influenced agricultural management and practices provides insight into the resilience and identity of rural people. This sheds light on why these areas, despite isolation, low productivity, conflict, armed presence, and challenging living conditions, are still seen by farmers as their place to be.

Keywords: Armed conflict, Colombia, milk production, sustainability

Contact Address: Natalia Triana-Angel, The Alliance of Bioversity International & CIAT, Trop. Forages Program, Cali, Colombia, e-mail: n.triana@cgiar.org

Breeding that integrates soils and cropping systems: The key to boosting climate adaptation

Sieg Snapp¹, Jeffrey Herrick², Powell Mponela³, Matthew Reynolds⁴, Eva Weitzien⁵, Mainassara Zaman-Allah⁶

¹CIMMYT, Sustainable Agrifood Systems, Mexico

²State Department, Food Security, United States

³CIMMYT, Nepal

⁴CIMMYT, Physiology and Remote Sensing, Mexico

⁵University of Wisconsin-Madison, Agronomy, United States

⁶CIMMYT, Global Maize Program, Zimbabwe

Recent articles have highlighted the importance of plant breeding for climate adaptation and prioritised specific traits for selection. What is often overlooked is the soil context, as agricultural expansion moves onto steep slopes that are highly erodible and degraded. Soil organic matter loss reduces soil moisture availability, exacerbating the impacts of droughts. Food security is at risk, which adapted crops can help mitigate. We present here a strategy to use edaphic information, as the missing ingredient in efforts to breed crops for the future.

The strategy includes the following: First, locate crop variety trials on soils that are representative of the type and health of soils where the crops are produced, including soils with low infiltration capacity, and poor water and nutrient availability.

Second, as a corollary to above, monitor soils at trial sites, including documenting soil parent material, texture, fertility and soil organic matter content as part of the metadata for each crop trial site. Failure to do so makes it nearly impossible to quantify crop response by soil type, and to determine if yield gaps are due to differences in environment (including crop management), genotype and the interaction.

Third, priorisation of crop traits which have long-term soil health benefits such as root system mass, solubilisation of phosphorus, nitrogen fixation and nitrification inhibition. For centuries we have bred exclusively for traits that maximise harvestable production. While this focus has resulted in tremendous improvements in crop yields, it has provided few crop options for amelioration of soil health and nutrient efficiency.

Crop breeding efforts that include on-farm screening are becoming wide spread, and a relatively inexpensive indicators of soil status could be integrated. For example, crop residues can be quickly quantified with image analysis, and rapid field assessments of soil organic carbon and soil aggregate stability can predict soil function. Satellitebased phenotyping has breeding plot-scale resolution for RGB and vegetative indices (and more indices will follow). In sum, we propose to improve crop breeding efforts through quantification of soil properties, and through selecting for plant properties that ameliorate soil health

Keywords: Climate adaptation, crop improvement, on-farm, root traits, soil health

Contact Address: Sieg Snapp, CIMMYT, Sustainable Agrifood Systems, Texcoco, Mexico, e-mail: s.snapp@cgiar.org

Technical efficiency with the adoption of climate-smart agricultural practices: Case of northern Togo

Jane Maureen Ngonjock Ebako¹, Essossinam Ali², Sabine Schlüter¹

¹University of Applied Sciences Cologne, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Germany ²University of Kara, Economics, Togo

Agriculture plays a vital role in the livelihoods of smallholder farmers. However, its dependence on increasingly unpredictable rainfall patterns has made it highly vulnerable to the effects of climate change. Climate-smart agriculture (CSA) has been heralded as a sustainable approach to increasing agricultural productivity while adapting to and mitigating climate change; however, the adoption of CSA practices is context and site-specific. Farmers have relied on their indigenous CSA practices, while government extension agents and non-governmental organisations (NGOs) are playing a vital role in promoting innovative CSA practices to farmers. There is a need to examine the efficiency of farm production with farmers' indigenous CSA practices, and innovative CSA practices promoted through intervention projects. Our study closes this gap by employing a cross-sectional study to compare the technical efficiency in farm production with the adoption of CSA practices from farmers' traditional knowledge and CSA practices from intervention projects. Additionally, it examines the drivers of farmers' adopted CSA practices. Through multistage sampling, we selected over 500 farm households in the Kozah prefecture of Togo and used a survey to collect primary data. The data were collected between January and March 2023. The stochastic frontier approach will be used to estimate technical efficiency in farmers' production, and the multivariate probit model will be employed to understand the drivers of the adopted CSA practices. 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, intervention projects, smallholder farmers, technical efficiency, traditional knowledge

Contact Address: Jane Maureen Ngonjock Ebako, University of Applied Sciences Cologne, Inst. for Technology and Resources Management in the Tropics and Subtropics (ITT), Robertstr. 2, 50999 Cologne, Germany, e-mail: janescorpy@gmail.com

Impact of climate-smart agricultural technology and gender-differentials on smallholder sunflower farmer's food-nutrition and water security

ABEEB OMOTOSO¹, ABIODUN OLUSOLA OMOTAYO², SAIDAT ADEBOLA DAUD³

¹North West University, Agricultural Economics and Extension, South Africa ²North West University, Food Security and Safety Focus Area Res. Group, South Africa ³Oyo State College of Agriculture and Technology, Agricultural Economics and Exten-

sion, Nigeria

Climate change poses a significant challenge to the agricultural system worldwide, particularly in a nation like South Africa, where water scarcity and food insecurity are prevalent. This study examines the impact of Climate-Smart Agricultural Technology (CSAT) adoption on gender-differential foodnutrition and water security outcomes in South Africa. Drawing on a combination of quantitative analysis and qualitative insights from gender-differentiated smallholder sunflower (Helianthus annuus L.) farming communities, a multistage sampling procedure was employed in selecting smallholder sunflower farmers across some selected villages in South Africa. To understand the linkages between CSAT, household's food-nutrition and water security outcomes (FNWS); endogenous switching regression (ESR) model was employed to achieve the objective. Herewith, water poverty index was used to measure the water security status, while dietary diversity index (Simpson Index) and calorie intake per adult equivalent were used to determine the foodnutrition security (FNS) of the households. The results show that femaleheaded smallholder sunflower farmers' FNS - dietary diversity and calorie intake increased by 28% and 30% respectively while the water poverty index reduced by 18%. On the other hand, that of their male counterpart increased by 21 % and 35 % respectively while the water poverty index reduced by 23 %, indicating that the farmers' decisions to adopt CSAT influenced their FNWS outcomes. Additionally, CSAT adoption is influenced by access to extension services, climate change information, and off-farm income. Therefore, the study concludes that CSAT adoption enhances water availability, crop yield and FNWS. Therefore, policy on investment in capacity-building initiatives to enhance farmers' knowledge and skills in CSAT adoption, and water resource management, particularly targeting the marginalised communities and women farmers would contribute to the increased implementation of CSAT adoption, thus, resulting in the overall FNWS in South Africa.

Keywords: Dietary diversity, food policy, rural development, water poverty

Contact Address: Abeeb Omotoso, North West University, Agricultural Economics and Extension, Mmbatho, Mafikeng, South Africa, e-mail: omotosoabeebtunde@yahoo.com

Factors influencing farmers' resilience in multi-disaster threats: A case study from Indonesia

Yosephine Avi Ayu Rembulan

Czech University of Life Sciences, Fac. of Tropical AgriSciences, Sustainable Rural Development, Czech Republic

Disaster is a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability, and capacity, leading to one or more of the following: human, material, economic, and environmental losses and impacts. In the past two decades, climate and weather-related disasters have quadrupled, impacting the agriculture sector and increasing vulnerability to agriculture communities. Located in the Ring of Fire of the World and globally known as the 'supermarket of disaster', Indonesia ranks 2nd among the high-est disaster-risk countries in the World. For an archipelago country where agriculture is the second contributor to GDP, it is crucial to ensure community resilience towards disaster for its agriculture communities.

Disaster risk reduction (DRR) is the process of reducing the impacts of disasters by identifying, assessing, and reducing the risks of disasters. Meanwhile, farmers' resilience to disaster will be reflected in their continuous adaptations to agriculture practices in a post-disaster context. The adaptation capacity of farming communities in Indonesia is dynamic as the communities face frequent disasters from both geological and hydrological hazards. Understanding their adaptation practices would be an effective tool in disaster recovery, rehabilitation, and preparedness work in disaster affected regions, especially those with most agriculture-based communities.

However, current studies primarily focus on single-hazard risks like volcanic eruptions or floods, leaving research gaps in investigating agricultural practices among communities confronting multiple disaster threats. There is also a crucial need to assess the applicability of resilience frameworks in Indonesia's unique context as a multi-hazard archipelago. In addition, the current emphasis on capacity-building for preparedness in DRR policies lacks integration with risk reduction in the agriculture sector.

Therefore, this study aims to explore the community's adaptation practices in agriculture in the post-disaster context in Indonesia: resources needed, the benefits, and the enabling and limiting aspects and how these contribute to resiliency. This study will show the importance of local actors and social governance in achieving community resiliency in disaster and climate change. It will open a dialogue for further research to fine-tune and improve DRR work in the increasingly challenging climate.

Keywords: Agroecology, Likert scale, livestock, perception, participatory workshop

Contact Address: Yosephine Avi Ayu Rembulan, Czech University of Life Sciences, Fac. of Tropical AgriSciences, Sustainable Rural Development, Kamycka 129 Suchdol, 16500 Prague, Czech Republic, e-mail: rembulan@ftz.czu.cz

Tank cascade system: A nature-based solution for achieving climate resilience in Sri Lanka's dry zone

Sujith S. Ratnayake¹, Sharon Mendonce², Teresa Borelli², Danny Hunter², Ajith Silva³, Thushani Dissanayake³

¹*Ministry of Environment, Sri Jayawardenepura Kotte, Climate Change Div., Sri Lanka* ²*The Alliance of Bioversity International & CIAT, Italy*

³*Healthy Landscapes: Managing Agricultural Landscapes in Socio-ecologically Sensitive Areas to Promote Food Security, Well-being and Ecosystem Health project, Sri Lanka*

The Tank Cascade System (TCS) is an ancient, man-made water management system unique to Sri Lanka's dry zone. An ecosystem in itself, the TCS consists of an intricate network of small to very large 'tanks' positioned along a gradient and connected through a series of canals. Within the system, paddy fields and dense forests coexist providing habitats for ecologically significant species. Historically, the system has been crucial in drought and flood mitigation. Furthermore, fully functioning TCSs harvest copious amounts of rainwater, which is primarily used for irrigation to enable year-round crop production by the farming communities of the cascade landscape. The system's important role in food security, rural livelihoods and local culture led to its designation as a Globally Important Agricultural Heritage System in 2017. Despite the TCS's significance, the system has been deteriorating, and its sustainability is threatened by widespread tank neglect, rapid land use changes and biodiversity lossthe impacts of which are exacerbated by the effects of climate variability. There is national interest in safeguarding the TCS, though. The system has been recognised in Sri Lanka's 2016–2025 National Adaptation Plan for Climate Change Impacts and within the 2021 Nationally Determined Contributions as an important Nature-based Solution (NbS) for strengthening national climate resilience. However, there is little evidence of this national support translating into on the ground action and of effective solutions to the challenges threatening TCS sustainability. This case study aims to fill these evidence gaps by sharing findings from research and project activities carried out under the Healthy Landscapes project (https://alliancebioversityciat.org/sites/default/ files/documents/Healthy\%20Landscapes\%20Project-Flyer_A4.pdf). With a special focus on mainstreaming biodiversity and strengthening cascade ecology, the project rehabilitated and promoted the sustainable management of the TCS. This case study will highlight pathways for TCS rehabilitation to strengthen its function as a NbS, including associated challenges and further opportunities. As the cascade landscape community plays an important role in climate adaptation and resilience within the country's dry zone, we also discuss their perceptions of current national policy and the importance of formulating localised adaptation strategies that benefit climate resilience, food security and rural livelihoods.

Keywords: Biodiversity, climate resilience, ecosystem rehabilitation, food security, nature based system, rural livelihoods, Sri Lanka

Contact Address: Sharon Mendonce, The Alliance of Bioversity International & CIAT, Via di San Domenico 1, 00153 Rome, Italy, e-mail: s.mendonce@cgiar.org

Tackling the nexus: Invasive alien species, mosquitoes, and health challenges evidence from Kenya

TASNEEM OSMAN¹, ERIC FÈVRE², CHRISTIAN BORGEMEISTER¹

¹University of Bonn, Center for Development Research (ZEF), Germany ²University of Liverpool, Inst. of Infection, Veterin. and Ecological Sci., United Kingdom

Climate change is expected to substantially alter biodiversity, leading to alterations in phenology, genetic composition, and species distribution while also affecting species interactions and ecosystem. Invasive alien species (IAS) have threatened the integrity of ecosystems throughout the world. They affect the species diversity of native ecosystems. Due to increasing 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. IAS reduce agricultural yields, irrigated croplands, grazing areas, and water availability, and contribute to the spread of mosquitoborne diseases. Mosquitoes are widely spread and transmit malaria and several arthropod-borne viruses. A particular example of IAS is Parthenium hysterophorus (Asteraceae). It is one of the world's most serious invasive plants that is 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. Currently, the spread of invasive plant species is a major problem in Kenya, where indigenous flora is replaced. The study sites are located in Baringo county. A total of 50000 mosquitoes were captured using a combination of different trapping techniques from six sites, three of them with IAS and three without. We identified 48 species. Mosquitoes was analysed for evidence of recent plant feeding using cold anthrone test. An overall low fructose positivity rate was found. Barcode technique was applied to identify plant food source using specific primers for a locus from the chloroplast genome, ribulose diphosphate carboxylase. This survey is an inventory of the mosquito population composition and of the abundance and richness of arboviruses. It provides an 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. Thus, it provides a beneficial knowledge for targeted control.

Keywords: Agricultural expansion, infectious diseases, invasive plants, *Parthenium hysterophorus*

Contact Address: Tasneem Osman, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: tasneemmoawia@hotmail.com

Adaptive capacity of apricot farming communities in response to changing water availability in Kyrgyzstan

JANNIKE VAN BRUGGEN¹, GULBARA OMOROVA² ¹Rhine-waal University of Applied Sciences, Faculty of Life Sciences, Germany ²Inst. of Water Problem & Hydropower Engineering, Kyrgyzstan

Apricot cultivation serves as a key source of income for the rural communities nestled within the Ferghana valley of southwestern Kyrgyzstan. Surface irrigation plays a crucial role in these agricultural systems drawing upon the vital glacial and snow-fed runoff from nearby mountains as the primary water source, crucially supporting irrigation needs particularly during the spring season. However, progressing climate change and increasing water demand propelled by population growth jeopardise these irrigated agricultural systems due to changes in water availability and its intra-annual distribution, thereby posing a threat to the sustainability of apricot cultivation in the region for the future. In the light of these challenges, this study aimed at better understanding the capacity of farmers to adapt their practices to the increasing uncertainty of water availability in order to secure their livelihood in the area.

Against this background, we embarked on a comprehensive exploration of farmers' current coping mechanisms and adaptation strategies to varying water availability for irrigation and related weather shocks. Employing a mixed-methods approach integrating qualitative (focus group discussions, key expert interviews) and quantitative (household surveys) tools, we assessed differences in coping as well as adaptation strategies and resulting adaptive capacity. Results provided insight into farmers' adaptive capacity in the light of their farming systems, socio-economic settings and the hierarchical structures within the irrigation scheme that farmers encounter themselves in, both spatially and in terms of decision-making power, which all affect their room to manoeuvre towards sustainable water management. Our findings derived from this research provide valuable groundwork for policy makers and other stakeholders to target interventions for enhancing the resilience of these apricot farming communities in the face of increasing uncertainty of water availability and weather extremes in the Ferghana valley.

Keywords: Agroforestry systems, Central Asia, climate change adaptation, irrigation, water management

Contact Address: Jannike Van Bruggen, Rhine-waal University of Applied Sciences, Faculty of Life Sciences, Marie-Curie-Str. 1, 47533 Kleve, Germany, e-mail: jannike.vanbruggen@hochschule-rhein-waal.de

Genetic analysis of heat tolerance in dairy cattle performing in sub-Saharan Africa

Richard Dooso Oloo¹, Chinyere Ekine-Dzivenu², Raphael Mrode², Julie Ojango², Gideon Kipkosgei², Gebregziabher Gebreyohanes², Jörn Bennewitz³, Ali Mwai Okeyo², Mizeck Chagunda¹

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

²International Livestock Research Institute (ILRI), Kenya

³University of Hohenheim, Dept. of Animal Genetics and Breeding, Germany

Given the ongoing climate change, selective breeding aimed at enhancing animals' resilience to rising temperatures, while still sustaining milk production, is crucial for the long-term viability of dairy systems in sub-Saharan Africa (SSA). However, specific indicators of heat tolerance have not yet been established for production systems in SSA, hindering their incorporation into breeding objectives. This study examined how milk production responds of cows to high heat load conditions as a measure of heat tolerance. A total of 65,261 first-parity weekly average milk yield records from 1,547 crossbred cows performing in semi-arid and semi-humid agroecological zones of Kenya were analysed. Temperature-Humidity Index (THI) was calculated from weather data generated online from the NASA POWER project and used as a measure of heat stress. Random regression models, including reaction norm functions, were fitted, adjusting for significant fixed effects. A THI value of 85 was chosen based on the population-level reaction norm to reflect heat stress conditions. The intercept of the reaction norm model (Intercept) for each cow was used as its mean production. Two resilience indicators were defined at THI 85: the slope of the reaction norm (Slope) reflecting a directional change in milk yield in response to heat stress and the absolute value of this slope (Absolute) showing the stability in milk production during heat stress conditions. Animals with <50 % Bos taurus genes and those performing in the semi-arid environment were the most thermotolerant. The Intercept, Slope, and Absolute had heritability estimates of 0.20 ± 0.05 , 0.25 ± 0.05 , and 0.12 ± 0.05 , respectively. Slope had a high negative correlation (-0.93±0.02) with Intercept, revealing that higher milk-producing cows are more vulnerable to heat stress and vice versa. A significantly moderate positive correlation (0.63 ± 0.19) was observed between Intercept and Absolute. This implied that lower milk-producing cows have a more stable production profile under heat-stress conditions. This study demonstrated the potential effectiveness of utilising reaction norm functions to assess the resilience of dairy cattle to heat stress in SSA. These findings hold significant implications for enhancing the heat tolerance of livestock species via genetic selection, particularly in low-income countries located in tropical regions.

Keywords: African tropics, climate change, heat stress, livestock, reaction norms

Contact Address: Richard Dooso Oloo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr. 17, 70599 Stuttgart, Germany, e-mail: richard.oloo@uni-hohenheim.de

Climate-smart agriculture practices influence on sorghum performance and soil water content in the central highlands of Kenya

Jane Omenda¹, Milka Kiboi², Felix Ngetich³, Gerd Dercon¹, Daniel Mugendi⁴, Jayne Mugwe⁵, Monicah Mucheru-Muna⁵, Jan Diels⁶, Roel Merckx⁶

¹International Atomic Energy Agency, Dept. of Nuclear Sci. and Applications, Austria ²Research Institute of Organic Agriculture (FiBL), Dept. of Intern. Coop., Switzerland ³Jaramogi Oginga Odinga University of Science and Technology (JOOUST), School of Agricultural and Food Sciences, Kenya

⁴University of Embu, Dept. of Water and Agricultural Resource Management, Kenya

⁵*Kenyatta University, Dept. of Agricultural Sciences and Technology, Kenya*

⁶*KU Leuven, Dept. of Earth and Environmental Sciences, Belgium*

In 2019 a long-term trial was established in the drylands of Tharaka-Nithi County Kenya. The objective was to provide research-based evidence on the synergistic effects of integrating soil and water conservation practices and soil fertility inputs on sorghum performance and soil water content. The experimental trial adopted a Randomised Complete Block Design with three levels of nitrogen fertilisation (120, 60, and 30 kg ha^{-1}) with four replications. We evaluated four soil and water conservation technologies (minimum tillage, mulching, tied ridges, and Managing Beneficial Interactions in Legume Intercrops (MBILI) along with a control (farmers' practice). The trial so far has consisted of a 9-season, five-year on-station trial with sorghum as the test crop planted during the long rainy season (March to July) and the short rainy season (October to February). Data were subjected to analysis of variance (ANOVA) using SAS version 9.4 and means were separated using Tukey-Kramer Honest Significant Difference Test ≤ 0.05 . Generally, significant (p \leq 0.05) improvement in soil moisture was observed by 40 and 35% by minimum tillage with mulch and tied ridges respectively. The highest yield (4.85 Mg ha⁻¹) and highest water use efficiency (1.17 kg m⁻³) were observed under minimum tillage treatment. Across the seasons, the best treatment combination for improving sorghum yield was minimum tillage with mulch at 120 kg N ha⁻¹ rate of the goat manure and mineral fertiliser. Our findings demonstrate that the use of minimum tillage with organic and inorganic fertility inputs can bridge the yield gaps in Kenya depending on the regional condition.

Keywords: Mineral fertiliser, minimum tillage, soil moisture, sorghum tied ridges

Contact Address: Jane Omenda, International Atomic Energy Agency, Dept. of Nuclear Sci. and Applications, 2444 Seibersdorf, Austria, e-mail: akothjaney@gmail.com

Empowering African farmers through digital knowledge exchange networks

Anton Eitzinger¹, Paswel Marenya², Chima Rickards², Mazvita Sheila Chiduwa³, Christian Feil¹, Monica Fisher²

¹*The Alliance of Bioversity International & CIAT, Climate Action, Colombia* ²*International Maize and Wheat Improvement Center (CIMMYT), Kenya* ³*International Maize and Wheat Improvement Center (CIMMYT), Malawi*

The rapid advancement of digital technologies has proven to be a transformative force in various sectors, including agriculture. This shift towards digitisation not only offers a cost-effective means to scale agricultural innovations but also enhances farmers' autonomy. By fostering bi-directional learning and sharing within digital platforms, farmers can access tailored advice that is targeted to their needs. This approach not only improves individual decision-making but also promotes social inclusion by broadening access to agricultural information. Despite the benefits, the integration of digital tools among smallholder farmers faces significant challenges. Issues such as limited access, insufficient digital literacy, and the absence of human-centered design are prevalent. Traditionally, farmers have depended on direct interactions with agricultural experts and community-based knowledge networks. While invaluable, these traditional methods lack the scalability and reach that digital platforms can provide. In regions where agriculture forms the backbone of the economy, conventional extension services are crucial for knowledge dissemination. However, these services, along with other traditional sources like agricultural shows and community plots, are often limited in their scope and impact. Digital channels, especially mobile technologies, offer a promising alternative. Features like digitally automated advisory services and speech-based interfaces provide accessible and practical solutions for farmers, bridging the gap between expert advice and on-ground application. We present findings from our pilots in Kenya and Zambia, where we implemented open digital channels to facilitate knowledge exchange between extension workers and farmers. These channels not only enabled efficient sharing of agricultural practices but also allowed for the collection of real-time feedback, enhancing the adaptability and effectiveness of the proposed solutions. Essential to the success of these initiatives is the ongoing capacity building for both agricultural advisors and farmers, ensuring they can fully leverage digital tools to optimise their agricultural practices. This research underscores the potential of digital networks to revolutionize agricultural knowledge dissemination and enhance farming practices across Africa.

Keywords: Digital, farming, knowledge, networks, tool

Contact Address: Anton Eitzinger, The Alliance of Bioversity International & CIAT, Climate Action, Cali, Colombia, e-mail: a.eitzinger@cgiar.org

A double jeopardy: Climate change affects both yield and grain quality of cereals in Ethiopia

Abel Chemura¹, Siyabusa Mkuhlani², David Abigaba³, Andrew Nelson¹

¹University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, The Netherlands

²*International Institute of Tropical Agriculture, Natural Resources Management, Kenya* ³*Potsdam Inst. for Climate Impact Res., Adaptation in Agric. Systems, Germany*

There is limited information on the impacts of climate change on grain quality and yet this yield component has significant implication for mal- and undernutrition in many parts of Africa especially among children. Using the crop model DSSAT, we asses the spatial and temporal variability of vield and vield components associated with grain quality (N uptake, canopy N, LAI, Tops N, grain N) for maize, wheat and barley in Ethiopia. We then assessed impacts of 1.5°C, 2°C and 3°C global warming levels on the yield and yield components. We find that there is considerable variation in both yield and yield components and over time. Areas in the central and western parts have higher yield and grain quality compared to those in the north and northeast of the country. Yield is positively correlated with LAI, N uptake, canopy N and grain N and negatively with soil N at maturity across the three crops. The highest variability in grain N over time was for wheat when compared to that of maize and barley. Under global warming levels, the changes in grain N followed the changes in yield with yield changes being more pronounced than grain N changes. The largest changes in grain N occurred in the central highland areas of the country, which have high yields for these crops. Under climate change, the impacts increased with the increase in magnitude of warming being highest under the 3°C level of warming for both crops. We therefore conclude that climate change will have an impact on both the yield and grain quality of maize, wheat and barley in Ethiopia and these effects on grain quality should be accounted for in climate impact studies of food systems to safeguard on health and nutrition aspects of food security especially for vulnerable groups.

Keywords: Climate impacts, food security, global warming levels, nutrition

Contact Address: Abel Chemura, University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, Enschede, The Netherlands, e-mail: a.chemura@utwente.nl

Water-saving irrigated rice cultivation promotes rice plant growth and improves farmers' income

Duy Hoang Vu

Vietnam National University of Agriculture (VNUA), Center for Organic Agriculture Promotion and Studies (COAPS), Vietnam

Rice cultivation contributes to a large amount of methane gas (CH_{4}) emissions through the decomposition of organic matter by microorganisms under anaerobic conditions. Water-saving irrigation technologies have been developed and introduced in various rice-growing regions. However, the implementation of these technologies is still limited and the principles of these technologies are not fully applied in practice. If the benefits of water-saving irrigation technologies for rice productivity and farmers' income are recognised, this may motivate farmers to apply the technologies in practice. The project was put into practice on a large area to evaluate the impact of water-saving irrigation technologies on rice crop growth and CH₄ emission reduction. The results show that, in addition to the benefits of saving water, these technologies also increase the growth of rice plants (number of tillers, biomass) and resistance to lodging, which leads to a higher yield. This is particularly beneficial in the tropics, which are often affected by monsoons and rainstorms at harvest time. In addition, the application of water saving irrigation technologies also promotes earthworm activity in the soil, which is of great importance for soil health and increases the oxygen content in the soil. In addition, water-saving irrigation technologies significantly reduce CH₄ emissions in rice fields, which are higher in transplanted rice than in direct-sowing rice. The reduction in CH_4 emissions can be converted into carbon credits, which increases the income of rice producers. These benefits are therefore the basis to encourage farmers to adopt water-saving irrigation technologies in sustainable agriculture and improve their income.

Keywords: Carbon credit, farmer income, methane gas emission, paddy rice

Contact Address: Duy Hoang Vu, Vietnam National University of Agriculture (VNUA), Center for Organic Agriculture Promotion and Studies (COAPS), Trau Quy - Gia Lam, 131000 Hanoi, Vietnam, e-mail: vdhoang87@gmail.com

Climate change modeling studies and scaling

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A hybrid modelling approach

Charting agroecological pathways: Multicriteria priority mapping for India's sustainable transition

Alok Sikka¹, Gopal Kumar¹, Abhijit Behera¹, Sudharsan Malaiappan¹, Smitha Krishnan²

¹International Water Management Institute (IWMI), India ²The Alliance of Bioversity International & CIAT, Multifunctional Landscapes, India

The coexistence of intensive cultivation in certain regions and rainfed, impoverished agriculture in others has not only failed to ensure adequate and balanced nutrition for a significant portion of the population but also engendered sustainability challenges. Particularly vulnerable are women and children, who disproportionately suffer from malnutrition. Amidst efforts to transition towards agroecology, observations have been varied, with some regions experiencing intended benefits while others find it challenging food security concerns. Despite substantial strides towards agroecological transition, India, as the world's most populous nation with limited land and natural resources, can't afford to lose focus on food security. Although natural farming practices promoted by the APCNF (Andhra Pradesh Community Natural Farming) have shown promise, their adoption has not reached desired levels. Insufficient knowledge base and incoherence between the natural farming movement and the national challenges and goals are the reasons. Consequently, a strategic approach to agroecological transition is imperative, necessitating the mapping of the regions, commodity and farming system based on multiple criteria aligned with national priorities and challenges. To delineate priority areas, commodities, and farming systems for the transition to agroecology, land use/land cover, land productivity, fertiliser consumption, rainfall distribution, groundwater availability, irrigation status, biomass and bioresource availability, soil organic carbon, and air temperature were used. Weightage for these parameters and sub-parameters was determined using the Analytical Hierarchy Process. The regions were categorised into three priority classes: high priority, medium priority, low priority for preparation of the priority maps. Additionally, factors such as farmer willingness, knowledge gaps, policy and programme support, local motivators, institutional structures, and governance will be incorporated, contingent upon data availability and compatibility. Ultimately, the mapping of priority areas and farming systems, in collaboration with stakeholders across the food system, will be pivotal for the successful transition to agroecology and its integration into the national policy framework.

Keywords: Agroecology, climate adaptation, digital agriculture, natural farming, priority mapping, resilience strategies

Contact Address: Gopal Kumar, International Water Management Institute (IWMI), Sustainable Water infrastructure & Ecosystems (SWIE), New Delhi, India, e-mail: g.kumar@cgiar.org

Modelling agroforestry adoption dynamics among smallholder farmers in rural Zambia: An agent-based approach

BRIGITTE RUESINK, LUZIA DEISSLER, ULRIKE GROTE

Leibniz University Hannover, Inst. for Environm. Economics and World Trade, Germany

Small-scale farming in regions like SSA faces numerous challenges exacerbated by climate change. Among these challenges, erratic weather patterns and limited resources pose significant hurdles to farmers' livelihoods. Agroforestry has emerged as a promising approach, offering benefits such as improved food security, income diversification, and increased resilience against environmental stresses. However, its adoption among smallholders is complex and influenced by various factors.

This study introduces an innovative approach to understanding agroforestry adoption dynamics among smallholder farmers in rural Zambia. Utilizing an agent-based simulation model, we aim to capture the nuanced decisionmaking processes of farmers within a virtual landscape. Unlike traditional approaches, this model considers individual aspirations, resource availability, and spillover effects from adopters to non-adopters, providing a more comprehensive conception of the adoption dynamics.

Drawing on data from 745 rural Zambian households collected as part of CIFOR-ICRAF's Fruit Tree Portfolio project in early 2022, our simulation model integrates socio-economic factors, such as land and farm characteristics, as well as cognitive and institutional factors. This methodological framework allows for the exploration of various scenarios and policy interventions, aiding in the design of targeted approaches to promote agroforestry adoption. By incorporating decision theories like the 'Capability approach' and 'Theory of planned behaviour', we enhance the model's realism and applicability.

This study contributes to both academic research and practical interventions in sustainable agriculture. By identifying key drivers and barriers to agroforestry adoption, we aim to inform policymakers and practitioners about effective strategies to improve smallholder livelihoods. Moreover, the agentbased modelling approach holds promise for future research in understanding complex agricultural livelihoods, offering a valuable tool for decisionmaking and policy formulation in agricultural development contexts.

Keywords: Agent-based modelling, agroforestry, aspirations, decision-making, resilience

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

Drought beyond the horizon drawing new borders along spatial clusters of agriculturally relevant extreme weather

Harold Achicanoy 1 , Julian Ramirez-Villegas 2 , Miranda Meuwissen 3 , Tobias Dalhaus 3

¹The Alliance of Bioversity International & CIAT, Climate Action (CGIAR), Colombia ²The Alliance of Bioversity International & CIAT, Climate Action (CGIAR), Italy ³Wageningen University & Research, Business Economics, The Netherlands

Climate variability and extreme weather events severely impair crop and livestock production worldwide. Coordinated adaptation efforts among policy makers and farmers are crucial to make the agricultural sector more resilient to these weather shocks. Here, we bridge the current understanding of extreme weather impacts on agriculture with climate science's understanding of the interconnectedness and synchronicity of climate patterns across the globe. More specifically, our global analysis identifies spatial clusters in which agriculturally relevant extreme droughts tend to occur at the same time in arable areas. We find that spatial clusters of extreme drought events do not necessarily coincide with agricultural climate zones. Moreover, a considerable number of clusters span across political borders indicating collaboration potential among countries involved (around 60% of the total number of the spatial clusters). In terms of transnational cooperation per continent, Africa $(\bar{84}\%)$, Europe (64%) and South America (57%) are the top three continents where the majority of extreme clusters share spans across country borders. We therefore offer a new perspective for coordinated adaptation efforts within regions of similar extreme weather exposure. In a global comparison, we find that in some regions, political unions such as the European Union, Mercosur or the African Union would enable a swift adjustment of political cooperation to better fit actual extreme weather exposure. In other regions however, extreme weather clusters span across political borders that promise little coordination between countries such as between Russia and Ukraine, Israel and Syria, or North Korea and South Korea. Among the coordinated adaptation strategies, we suggested the use of financial mechanisms such as weather index-based insurance.

Keywords: Coordinated adaptation, drought, spatial clusters, weather extremes

Contact Address: Harold Achicanoy, The Alliance of Bioversity International & CIAT, Climate Action (CGIAR), Calle 32 A norte #2b-55 apto 706b, 760050 Cali, Colombia, e-mail: h.a.achicanoy@cgiar.org

Combatting sand and dust storms: The performance and value of sustainable land management in arid to subtropical areas

Stefan Strohmeier¹, Mira Haddad², Joren Verbist³, Niels Verouden⁴, Dominik Paireder¹, Emma Izquierdo-Verdiguier⁵, Platon Patlakas⁶, Christos Stathopoulos⁶, Ioannis Chaniotis⁶, Nick Middleton⁷, Feras Ziadat⁸, Akmal Akramkhanov³

¹BOKU University, Inst. of Soil Physics and Rural Water Management, Austria ²International Center for Agricultural Research in the Dry Areas (ICARDA), Jordan ³International Center for Agricultural Research in the Dry Areas (ICARDA), Lebanon ⁴Independent researcher, The Netherlands

⁵BOKU University, Inst. of Geomatics, Austria

⁶National and Kapodistrian University of Athens, Dept. of Environmental Physics and Meteorology, Greece

⁷University of Oxford, St Anne's College, United Kingdom ⁸Food and Agriculture Organization of the United Nations, Italy

Around one fifth of the earth's landmass, covered by deserts, unremittingly feeds erosive winds and the atmosphere with sediments. Whilst the hyper arid areas may irrecoverably continue providing major sources for Sand and Dust Storms (SDS), the arid to subtropical climatic zones, surrounding the global deserts, serve as the utmost important shelter belts. Those dry to subtropical regions host an immense agro-ecosystem diversity, largely cultivated by smallholder and subsistence farmers. Besides their critical role in food production, the smallholders' contribution to supporting and regulating ecosystem services is key, inevitably linked with halting desertification.

Our study tackles the performance assessment of selected Sustainable Land Management (SLM) strategies in arid to subtropical zones – specifically their role in combatting SDS through providing vegetation cover and/or resilient soil structure. In our preliminary attempt, four SLM approaches were i) spatially mapped towards their scaling-potential, and ii) investigated for their effectiveness in reducing SDS emissions within the Dust Belt area ranging from Morocco to China. Google Earth Engine was used to map different levels of suitability and impact of selected SLM: (1) micro-water harvesting based plantation of shrubs, (2) air seeding of tree a species (saxaul), (3) broadcasting of perennial legumes (sulla) and (4) conservation (reduced tillage) agriculture. Combining the SLM suitability with a global SDS source area risk map allowed the estimation of SDS reduction performance withdrawing information from case studies and expert knowledge. A stepwise efficiency

Contact Address: Stefan Strohmeier, BOKU University, Inst. of Soil Physics and Rural Water Management, Vienna, Austria, e-mail: stefan.strohmeier@boku.ac.at

assessment of integrated SLM scaling was conducted using Linear Programming (LP). The developed LP model strives towards minimising the SDS risk through successive out-scaling of SLMs, constrained by the extent of suitable areas and total costs.

Our approach links SLM performance to costs, resulting in a transparent decision support mechanism tailored for application at the country, regional or global level. Thus, to identify suitability and evaluate the integrated effectiveness of multiple SLMs on combatting SDS that threaten ecosystems and our life on land.

Keywords: Wind erosion, sand and dust storms, sustainable land management, land suitability

Defining a target population of environments in Africa for *Brachiaria* sp. and guinea grass breeding

Brayan Mora¹, Rosa Noemi Jauregui¹, Lizeth Llanos Herrera¹, Peters Michael², Rein van der Hoek³, An Notenbaert⁴

¹The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

²The Alliance of Bioversity International & CIAT, Kenya

³The Alliance of Bioversity International & CIAT, West Africa, Senegal

⁴*The Alliance of Bioversity International & CIAT, Kenya*

The Tropical Forages breeding programme based in Colombia, aims to develop superior cultivars for particular target population of environments (TPE). A TPE consists of a set of environments and future conditions where the newly developed cultivars will be grown. Defining the TPE and assessing its heterogeneity is a key step to improve selection efficiency and genetic gain in the breeding program. For this, a spatially- explicit environmental characterisation and cluster analysis was conducted in Southeast Africa (Ethiopia, Kenya, Rwanda, Uganda, Tanzania, Zambia Malawi, Zimbabwe, Botswana, Lesotho, Eswatini and South-Africa) and West Africa (Senegal, Mali, Ghana and Burkina Faso). The defined TPE in Africa, were used as reference to conduct an analysis of similarity in Colombia to identify potential areas with similar edaphoclimatic conditions. In this way, the correlation between the selection environments in Colombia and the TPEs in Africa can be determined.

The environmental characterisation included key climate indicators and soil conditions that explain the performance of forages. Monthly climate variables were calculated using daily data collected between 1983 and 2022, at a spatial resolution of 5 km². Soil property data, on the other hand, are relatively constant over time, with only one data point per pixel. After calculating the climate indicators, the dimensionality reduction technique known as Empirical Orthogonal Functions (EOF) was applied. This technique captures the greatest variability of the data and represents it through principal components, considering the temporal and spatial dimensions of the data. Subsequently, environmental clusters were generated in the target countries using the classic clustering algorithm K-Means. This method groups pixels (areas of 5 km^2) considering the principal components generated through EOF. K-Means was then used predict these groups in Colombia using the principal components calculated for this country. Finally, the process was adjusted by calculating the similarity between the centroid of one of the groups defined in Southeast and West Africa and the same group using the prediction for Colombia. A percentage of pixels (10%, 20%, 30%) representing high similarities in terms of climate and soil conditions of each identified cluster was selected as the potential area for locating the selection environments.

Keywords: Forage breeding, Panicum urochloa

Contact Address: Rosa Noemi Jauregui, The Alliance of Bioversity International & CIAT, Trop. Forages Program, KM 17 RECTA CALI PALMIRA, 763537 Cali, Colombia, e-mail: r.jauregui@cgiar.org

Impacts of climate change on fisheries resources and food security in Egypt

Sahar Mehanna

National Institute of Oceanography and Fisheries (NIOF), Fish Population Dynamics, Egypt

Fast growing of global population and increasing demand on the seafood are taking place in the same time of declining the food resources especially the fisheries resources. More than 30 thousand species of fish live in our oceans, many of which are at risk of being affected by overfishing, pollution, IUU, invasive species and climate changes. As around 200 million people globally depend on fishing for their livelihood, it is vital to operate the fishing sustainably to avoid collapse of fish stocks. Thus, given the billions of people dependent on fisheries in some capacity, there is an urgent need to account for the effects of different challenges especially climate changes facing these resources and identify practical adaptations when building climate-resilient sustainable-development strategies. From land to sea, climate changes have affected wildlife and biodiversity by intensifying pre-existing stressors such as invasive species, diseases and habitat loss. Due to ocean warming, acidification, sea-level rise and de-oxygenation, the maximum catch potential of different fish stocks in some seas may be decline by up to 30 % by the 2050s. Climate change might also lead to the loss of 10-40 % of species suitable for marine aquaculture in the tropics and subtropics by 2050s. Understanding how climate changes will affect key commercial fish species and preparing for these changes will help ensure sustainable fishing. Fish stocks and marine habitats, however, are vulnerable to the physical and biogeochemical oceanic changes associated with rising greenhouse gases. These changes to fish stocks, and subsequent impacts on fish production, have substantial implications for the UN Sustainable Development Goals. The present paper will provide the information that marine stakeholders need to explore the potential impacts of climate change on Egyptian fisheries and to develop adaptation strategies.

Keywords: Acidification, de-oxygenation, egypt, fishery resources, global warming, governance, mitigation, monitoring

Contact Address: Sahar Mehanna, National Institute of Oceanography and Fisheries (NIOF), Fish Population Dynamics, P.O. Box 182, Suez, Egypt, e-mail: sahar_mehanna@yahoo.com

Toward a better future, how resilient food systems enhance the implementation of the SDGs, an Austrian case study

Carolin Auwärter¹, Laura Hundscheid¹, Mette Vaarst², Andreas Melcher¹

¹BOKU University, Dept. of Sustainable Agricultural Systems, Austria ²Aarhus University, Dept. of Animal and Veterinary Sciences - ANIVET Management and Modelling (MAMO), Denmark

The globalised food system's environmental, nutritional, and socio-economic issues are of utmost importance in pursuing the Sustainable Development Goals (SDGs). Hence, a transformation towards more resilient and sustainable food systems is crucial. Since the actions in one part of the world result in impact in another, so it is important that the transformation happens on all scales. For Austria, a trans- and interdisciplinary network of 19 universities, the UniNEtZ project, is working to accomplish the SDGs. For this purpose, a report was published with a catalogue of options and measures that are aimed at the SDGs and mention resilience as a fundamental principle. This case study aims to investigate how resilience in the context of food systems can contribute to achieving the SDGs. The Stockholm Resilience Centre's (SRC) framework, which contains seven principles for enhancing resilience in socio- ecological systems, was used as a guide for the qualitative content analysis of the UniNEtZ options report. The results show that the food system approach makes it possible to identify trade-offs and synergies along the value chain and between the different actors. Resilience vields the potential to complement the SDGs for transformation purposes. The results confirm that the UniNEtZ options offer a comprehensive range of measures that cover the principles of the SRC framework. However, some options lack in-depth qualitative analyses and tangible measures to enable resilient transformation. In line with other studies, the results indicate an imbalance in primary production and consumption measures. Thus, the UniNEtZ options should be expanded. For that national future studies that explore other aspects of the food system, such as processing, distribution, and waste management are recommend. This work emphasis a better future for all by including primary production and consumption measures and involving farmers, policymakers and society.

Keywords: Austria, consumption, food systems, primary agricultural production, resilience, sustainable development goals, synergies, trade-offs, zero hunger

Contact Address: Carolin Auwärter, BOKU University, Dept. of Sustainable Agricultural Systems, Vienna, Austria, e-mail: cauwaerter@gmx.de

Drivers of farmers' adaptive behaviour to climate change: The 3F-SEC framework

ALEXANDER CANO, BENTE CASTRO-CAMPOS Justus Liebig University Giessen, Inst. of Agricultural Policy and Market Research, Germany

The impact of climate change on farmers and their agricultural activities is of increasing concern, including crop losses and increasing food insecurity. In recent years, the literature on farmers' adaptive behaviour about climate change has increased. However, no studies have been conducted to classify and systematize all the factors that influence adaptive behaviour. To fill this knowledge gap, we aim to address the following research questions: (1) What are the drivers influencing farmers' decision-making behaviour regarding climate change adaptation measures? (2) How do these influential factors interact with each other and shape individuals' adaptive behaviours? For this purpose, we conduct a systematic literature review using the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) protocol. In total, we analyse eighty-seven articles from Web of Science and identify one hundred and eighty drivers of farmers' adaptive behaviour. As a result, we categorise them into six different groups: socio-demographic characteristics of the farmer, farms' characteristics, financial aspects, situational context, experience-based aspects, and cognitive factors. In addition, we introduce an organisational framework - 3F-SEC -, which provides a holistic representation of all elements influencing farmers' decision-making process when selecting climate change adaptation measures. In addition, four cases of farmers from central Colombia are included and their adaptive experiences are discussed in alignment with the proposed framework. We conclude that this framework serves as a visual representation without establishing causal relationships between them. Moreover, the complex interaction that exists between the identified factors means that they have mutually reinforcing effects on each other. It should also be kept in mind that the context of each individual farmer generates variations in their behaviour.

Keywords: Adaptation, adaptive behaviour, climate change, drivers of behaviour, 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

Investigating the effects of climate change on national parks in Iran

Naghmeh Mobarghaee¹, Houman Liaghati², Saba Shokrollahi³

¹Shahid Beheshti University, Environmental Planning, Iran

²Shahid Beheshti University, Environmental Sciences Research Institute, Iran

³Tehran University, Environment, Iran

A national park is a large area of nature that governments protect its ecosystem and create a safe and suitable environment for the growth and reproduction of plant and animal species with a rich biodiversity. These natural areas include forest, pasture, grove, plain, river, lake and mountain.

Also, national parks are suitable areas for educational, research and tourism activities, which have special ecological values. For the proper protection of biodiversity, genetic resources, ecological integrity and landscapes, any human activities other than conservation measures are prohibited in these areas. For this reason, national parks have a stronger legal support than other protected areas. However, local residents benefit from the ecosystem services produced by these national parks.

In Iran, since 1970, 31 national parks have been registered in 17 provinces of the country with an area more than 2 million hectares, which include different climatic conditions, animal species and vegetation of country. Climate changes in recent years have left many effects in Iran. Therefore, these effects on national parks as hotspots with biological diversity can be seen with greater intensity. Surveys show that in Iran, climate changes show themselves mostly with an increase in temperature and a decrease in precipitation. In this research, the effects of climate change on the country's national parks have been estimated using climate change measurement and prediction models. The results show that a large part of national parks in the country are exposed to moderate to severe climate changes, which shows the necessity of adaptation policy in these ecosystems.

Keywords: Climate change, impact assessment, Iran, national parks

Contact Address: Naghmeh Mobarghaee, Shahid Beheshti University, Environmental Planning, Velenjak, Tehran, Iran, e-mail: n_mobarghei@yahoo.com

Raising adaptive capacities through agrometeorological learning – lessons from Burkina Faso and Senegal

Sprenger Arvid¹, Silke Stöber², Eric Kabre Touinrimba³, Fatimata Diop⁴

¹*Freie Universität Berlin, Geographies of Global Inequalities, Germany*

²Humboldt-Universität zu Berlin, Centre for Rural Development (SLE), Germany

³Association Koassanga, Burkina Faso

⁴Association pour la Promotion de l'Agroforesterie et de la Foresterie (APAF), Senegal

Climate change poses significant challenges to farmers worldwide, impacting crop yields and exacerbating food insecurity. To address these challenges, enhancing agricultural resilience is crucial. One effective approach is empowering farmers with tools for informed decision-making, such as local weather observation and agrometeorological learning. A three-year collaborative research project, part of the Nutrigreen initiative supported by the European Research Area Network Cofund (ERA-NET) Food Systems and Climate (FOSC), examined the feasibility and impact of such initiatives in Senegal and Burkina Faso.

Data on daily maximum and minimum temperatures and rainfall in eight rural villages in semi-arid agro-climatic zones were collected and analysed from 2022 to 2023. This data, collected by trained observers, facilitated by NGOs, and analysed by students, was compared to long-term averages. The results were fed back to the local weather observers on a quarterly basis and combined with focus group discussions to evaluate the process. For the analysis of historical weather data, re-analysed open source weather data provided by the World Bank was used. Results of ombrothermal diagrams showed decreased rainfall and increased maximum temperatures, with variations among villages and years compared to the long-term average from 1991 to 2020. Rainfall occurred mainly in July and August, while the other months of the rainy season - June, September and October - were comparatively dry. The number of rainy days varied widely between villages and years, with the largest difference in Razoutenga village of Burkina Faso being 21 days in 2022 and 40 days in 2023.

Despite challenges, such as poverty, food insecurity, illiteracy, and logistical issues, the experiment had positive outcomes. Communities expressed a strong demand for improved rainfall information, and observers were empowered to read and interpret climate data, bridging the knowledge gap between science and local communities. This study underscores the importance of localised climate information and community engagement in building agricultural resilience. However, to maximise benefits, agro-meteorological learning should be further integrated with support for agro-ecological farming practices, directly impacting food security and smallholder incomes.

Keywords: Agroecology, agrometeorology, Burkina Faso, climate change, climate information, Senegal, weather observer

Contact Address: Sprenger Arvid, Freie Universität Berlin, Geographies of Global Inequalities, Transvaalstraße 11, 13351 Berlin, Germany, e-mail: sprengea57@zedat.fu-berlin.de

How earth observation closes the gap between *in situ* greenhouse gas measurements and regional earth system modelling in West Africa

Verena Huber Garcia¹, Frank Thonfeld¹, Jonas Meier¹, Kenneth Aidoo², Ferdinand Tornyie², Souleymane Sy³, Jan Bliefernicht³, Harald Kunstmann³, Ursula Gessner¹

¹German Aerospace Center (DLR), German Remote Sensing Data Center, Germany ²United Nations University, Institute for Natural Resources in Africa, Ghana ³University of Augsburg, Institute of Geography, Germany

West Africa has contributed little to global greenhouse gas (GHG) emissions. However, it is already severely affected by climate change through rising temperatures and shifting precipitation patterns. At the same time, it is experiencing one of the fastest population growth rates worldwide. As a consequence, land degradation is proceeding, the competition for land is rising whereas yields are expected to decline. Meanwhile, the intensification of land use is emitting more GHGs, again. The aim of the CONCERT project is therefore to identify opportunities for a win-win land use mosaic that a) ensures food security, b) reduces GHG emissions and land degradation, and c) mitigates climate change. To accomplish this, the existing meteorological and GHG observation network in West Africa has been extended and upgraded within the project focus region of northern Ghana. The *in situ* measurements are the basis for estimating and projecting GHG emission budgets at the country and regional scale using a fully coupled regional Earth System Model (ESM) tailored to West Africa. For closing the gap between point scale and large-scale modelling, precise information on vegetation parameters at various spatial scales and updated high-resolution land cover and vegetation maps are needed. While Earth Observation can provide valuable datasets on vegetation dynamics, freely available global products often lack the necessary spatial and temporal resolution over West Africa. Within the CONCERT project, we therefore focus on assessing and enhancing existing biophysical parameter time series, generating new time series at higher resolution, and updating land use and land cover maps. A particular emphasis is placed on evaluating leaf area index (LAI) time series and filling gaps caused by cloud cover during the rainy season. On the one hand, we provide a high-resolution Sentinel⁻² based LAI product at a 20 m resolution. On the other hand, the Copernicus 300 m LAI product was enhanced and provided to the modelers. By aggregating the high-resolution LAI to the lower resolution, a statistically robust validation of the 300 m LAI is achieved. This enables assessing the scalability of the modelled GHG emissions to the whole study area

Keywords: Earth observation, greenhouse gases, LAI, time series, West Africa

Contact Address: Jonas Meier, German Aerospace Center (DLR), Earth Observation Center, Muenchener Strasse 20, 82234 Wessling, Germany, e-mail: jonas.meier@dlr.de

Climate change threatens the viability of temperate fruit orchards in the mediterranean region

Lars Caspersen¹, Katja Schiffers¹, Antonio Picornell², Atifullah Shinwari¹, Jose A. Egea³, David Ruiz³, Alvaro Delgado³, Mehdi Ben Mimoun⁴, Adnane El Yaacoubi⁵, Ossama Kodad⁶, Haïfa Benmoussa⁴, Erica Fadón⁷, Javier Rodrigo⁷, Eike Luedeling¹

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

²University of Malaga, Dept. of Botany and Plant Physiology, Spain

³CEBAS-CSIC, Dept. of Plant Breeding, Fruit Breeding Group, Spain

⁴*University of Carthage, Inst. National Agronomique de Tunisie (INAT), Lab. GREEN-TEAM (LR17AGR01), Tunisia*

⁵University Sultan Moulay Slimane, Higher School of Technology Khenifra, Morocco ⁶National School of Agriculture of Meknès (ENAM), Department of Arboriculture and Viticulture, Morocco

⁷Centro de Investigación y Tecnología Agroalimentaria de Aragón (CITA), Dept. of Plant Science, Spain

Southern Spain and northern Africa have many productive orchards of temperate fruit and nut tree species with high economic relevance. However, these orchards are threatened by rising temperatures both during the main cultivation season and during the winter months. Most temperate-zone trees enter a dormant stage around the time of leaf fall and then require exposure to chilling and heat to resume growth, flower, and ultimately bear fruits. Changes in temperature during the winter can lead to shifts in bloom timing. When agroclimatic requirements are not fully met, trees may show irregular or inhibited flowering, which may entail reduced yield and compromised fruit quality. To project future climate change impacts on Spanish and north African orchards, we calibrated the phenology model PhenoFlex with flowering data of four temperate fruit and nut tree species (apple, apricot, almond, pistachio) from four locations in southern Spain, Morocco, and Tunisia, covering 49 cultivars in total. We predicted bloom dates and potential bloom failure rates (in case agroclimatic requirements are not fulfiled) for present and future conditions. We projected bloom dates and potential bloom failure rates for two periods (2035 – 2065, 2070 – 2100), four climate change scenarios (SSP126, SSP245, SSP370, SSP585), and a collection of global circulation models (14 – 18, depending on the scenario). We observed two main patterns when comparing the projected bloom dates under future and present conditions: unchanged bloom times for almonds in Morocco and moderate

Contact Address: Lars Caspersen, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Im Erlengrund 35, 53175 Bonn, Germany, e-mail: lcaspers@uni-bonn.de

to strong delays in flowering for almonds and pistachios in Tunisia, almonds and apricots in southern Spain, as well as apples in Morocco. Additionally, we projected increasing rates of unfulfiled thermal requirements for several apricot cultivars in southern Spain in the short run (2035 - 2065), and for pistachios and almonds in Tunisia and southern Spain in the long run (2070 - 2100) under pessimistic climate scenarios. We observed significant differences among cultivars in the phenology shift and bloom failure rates for apricots and almonds, indicating considerable variation among cultivars in their resilience to warming winters.

Keywords: Agroclimatic requirements, climate change adaptation, dormancy, dynamic model, phenology

Agricultural water demand for agroforestry systems in the Sahel in a changing climate

Nele Gloy¹, Abel Chemura^{2,1}, Bernhard Schauberger^{3,1}, Christoph Gornott^{4,1}

¹*Potsdam Institute for Climate Impacts Research, RD2 - Climate Resilience, Germany*

²*University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, The Netherlands*

³University of Applied Sciences Weihenstephan-Triesdorf, Dept. of Sustainable Agriculture and Energy Systems, Germany

⁴University of Kassel, Fac. of Organic Agricultural Sciences, Germany

In many areas of the world, there is a growing pressure on agricultural water demand due to climate change and population growth but the expected amounts are unknown and depend on climatic conditions and respective cropping systems. The Sahel in sub-Saharan Africa is a particular vulnerable region, where water resources are often already overexploited which puts especially pressure on water resources during dry seasons. Many smallholder farmers cultivate their crops in mixed systems, intercropped with other annual plants or perennials (e.g. agroforestry). While water demand of specific (irrigated) single crops is mostly known, this remains still vague for more complex systems. However, the assessment of water demand and water use efficiency is crucial for successful implementation and sustaining production especially under changing climatic conditions. This study will quantify the water demand of a common agroforestry system in the Sahel (e.g. sorghum and Faidherbia albida) using the process-based crop model APSIM-X for different development stages during the crop season. We consider interactions that will have a potential effect on the evapotranspiration of the system such as shading, microclimate, and increased organic matter transfer, as well as competition in root water uptake. In a second step we aim to soft couple the outputs with a hydrological model (SWIM) to assess the water availability in the catchment. To shed light on location-specific estimates on agricultural potentials and required water for agroforestry systems in the Niger Basin in future periods, we will feed the model with downscaled climate projections (12.5km) for three different scenarios (SSP1-RCP2.6, SSP3-RCP7.0, SSP5 RCP8.5).

Keywords: Agroforestry, climate change, Sahel, water demand

Contact Address: Nele Gloy, Potsdam Institute for Climate Impacts Research, RD2 - Climate Resilience, Telegraphenberg A 62, 14412 Potsdam, Germany, e-mail: nele.gloy@pik-potsdam.de

Response of dryland crops to climate change: Understanding the nexus between water and nutrient use efficiency, nutritional security, and food safety

Mariana Vezzone, Gerd Dercon, Christina Vlachou, Pooja Bhatnagar-Mathur

International Atomic Energy Agency (IAEA), Austria

One of the most significant global challenges is the alleviation of hunger and food insecurity. This challenge is further compounded by the anticipated impact of climate change on agricultural yields in various world regions, particularly in dryland regions where water scarcity and temperature extremes affect crop production, which may have implications for food availability and quality. These alterations subsequently affect water and nutrient use efficiency. Moreover, studies have demonstrated that shifting climate conditions create environments conducive to mycotoxin-producing fungi and increased uptake of heavy metals.

The multifaceted challenges posed by climate change to agricultural systems create a nexus between water and nutrient use efficiency, nutritional security, and food safety. However, the scarcity of integrated studies evaluating all these dimensions underscores the need for comprehensive research endeavours. Consequently, to enhance understanding of dryland crop responses to a shifting climate, it is imperative to implement integrated strategies that promote climate-resilient agricultural practices. This integrated and multidisciplinary approach can be achieved by utilising the capabilities of three laboratories of the Joint FAO/IAEA Centre of Nuclear Techniques in Food and Agriculture: Food Safety and Control Laboratory (FSCL), Plant Breeding and Genetics Laboratory (PBGL), and Soil and Water Management and Crop Nutrition Laboratory (SWMCNL).

This FAO/IAEA project, entitled "Ensuring food security and safety by future-proofing dryland crops under climate change", funded by the UK government, aims to reinforce existing methodologies and identify novel applications on the use of nuclear and related techniques to enhance genetics, optimise resource utilisation, improve nutrition, and ensure the safety of food and feed under elevated CO₂ levels, high temperatures, and drought conditions. Furthermore, the initiative aspires to develop a global network for investigating the impact of climate change on the food and nutritional security of dryland crops, while developing mitigation strategies and future readiness under challenging climate conditions. Through this interdisciplinary project, FAO/IAEA will further support Least Developed Countries to mitigate the effects of climate change on global nutrition.

Keywords: Climate change, dryland crops, food safety, nutritional security, resource use efficiency

Contact Address: Mariana Vezzone, International Atomic Energy Agency, Soil and Water Management and Crop Nutrition Laboratory, Vienna, Austria, e-mail: m.rabello@iaea.org

Assessing the impacts of climate change on agricultural land suitability for cash and staple crops in Ghana and Benin

Mélika Kèmi Vodoun
hessi 1 , Lisa Murken 2 , Abel Chemura
 3 , Kwame Hackman 1 , Christoph Gornott
 4,2

¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

²Potsdam Institute for Climate Impact Research (PIK), Germany

³University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of Natural Resources, The Netherlands

⁴University of Kassel, Fac. of Organic Agricultural Sciences, Germany

Climate change poses significant challenges to agricultural land suitability and crop production worldwide, particularly in vulnerable regions like Sub-Saharan Africa. This study investigates the impact of climate change on agricultural land suitability for twelve crops in Ghana and Benin. The analysis utilises land suitability assessment methodologies, incorporating climatic and soil data. Through the study, we aim to address the scientific gap regarding the impact of climate change on crop land, in order to support sustainable and climate-resilient agriculture in the region.

The study area includes Benin and Ghana, where agriculture plays a crucial role in the economy and employs a significant portion of the population. The climate data is from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP), soil pH data from the International Soil Reference and Information Centre (ISRIC). This data is employed by the EcoCrop model to assess thermal and precipitation suitability scores for each crop by taking the crop requirements from the Global Agro-Ecological Zones (GAEZ) v4 Data Portal. EcoCrop evaluates temperature and precipitation ranges during growing seasons, considering optimal and permissible conditions for crop growth and also soil pH. The minimum suitability score between climate and soil factors determines overall crop suitability.

Results indicate varying impacts on crop suitability over time and across different climate scenarios (SSPs). Notably, maize exhibits increasing viability compared to rice and millet in response to worsening climate conditions. However, there are fluctuations and decreases in suitability for maize and millet across different SSPs and timeframes.

The study underscores the importance of understanding climate change impacts on agricultural land suitability for informed decision-making and adaptation strategies. By identifying crops and regions most affected by climate change, policymakers and stakeholders can prioritise interventions to support sustainable and resilient agriculture in Ghana and Benin.

Keywords: Agricultural land suitability, climate change, crop suitability, Ecocrop, land use

Contact Address: Mélika Kèmi Vodounhessi, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Ouagadougou, Burkina Faso, e-mail: vodounhessi.m@wascal.org

A discrete stochastic programming approach to quantify the financial value of seasonal forecasts to smallholder farmers in the Central Rift Valley of Ethiopia

SAMUEL KAYAMO¹, CHRISTIAN TROOST¹, LIVIA RASCHE², THOMAS BERGER¹

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

²University of Hamburg, Research Unit Sustainability and Climate Risks, Center for Earth System Research and Sustainability, Germany

Seasonal climate forecasts (SCFs) have the potential to reduce agricultural risk by providing valuable insights into upcoming weather patterns and fostering resilience and adaptability in response to climate variability and change. However, their use remains limited among smallholder farmers, particularly in developing countries like Ethiopia, due to a lack of understanding of its economic value. To assess this value, we designed a discrete stochastic programming model (DSP) implemented using the MPMAS (Mathematical Programming-based Multi Agent Systems) software package. The DSP estimates the economic benefit of seasonal rainfall forecasts for smallholder farmers in the Central Rift Valley of Ethiopia given different adaptation options to forecasted and observed weather trajectories, such as adjusting sowing month, crop choice, tied-ridging, and N-fertilisation. Yield estimates for crop management strategies and 2400 resampled weather trajectories were simulated using the FAO-developed Aqua-crop model and inserted in the DSP. The DSP maximises the expected monetary value determining the optimal sequential management response to rainfall patterns observed throughout the season considering weather observed until the respective decision point and the potential weather and associated risk for the remainder of the season. This distinctive approach ensures that the DSP takes into account the embedded risk that farmers face instead of assuming all decisions are taken at the beginning of the season. This avoids an important, but common conceptual bias, when comparing the expected monetary value with and without the forecast. Initial findings from the model suggest that farmers have intricate ways to respond to ongoing weather observations and it requires detailed analysis in which situations an imperfect forecast can really generate economic value for smallholder farmers.

Keywords: Climate adaptation, embedded risk and discrete stochastic programming, farm level model, value of information

Contact Address: Samuel Kayamo, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), 70593 Stuttgart, Germany, e-mail: samuel.eliaskayamo@uni-hohenheim.de

The ongoing journey of intercropping modelling: Key insights from the model developers and expert users on fundamental assumptions

Adam Muhammad Adam¹, N. Falconnier Gatien², Claas Nendel³, Marcos Lana⁴, Ken Giller⁵, Frank Ewert⁶, Carsten Marohn¹, Georg Cadisch¹, Rezai Ehsan Eyshi³, Jing Yu³, Mortis Laub⁷, Meine van Noordwijk⁸, Betha LUSIANA², ANTOINE COUËDEL², VIMBAYI CHIMONYO⁹, MICHAEL KERMAH¹⁰, Myriam Adam¹¹, Marc Corbeels¹², Amit Kumar Srivastava³, Sabine J. SEIDEL¹³, THOMAS GAISER¹³, PACSU SIMWAKA⁴, ERIC KOOMSON¹, JOHANNA VOLK¹, UPENDRA SINGH¹⁴, JACOUES FILS PIERRE¹⁴, WILLINGTON PAVAN¹⁴, ALEX C. RUANE¹⁵ ¹University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany ²AIDA, Univ Montpellier, CIRAD, Montpellier, France, ³Leibniz-Centre for Agric. Landscape Res. (ZALF), Germany ⁴Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden ⁵Wageningen University & Research, Plant Production Systems, The Netherlands ⁶University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany ⁷ETH Zurich, Switzerland

⁸*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya*

⁹CIMMYT, Sustainable Agrifood Systems, Zimbabwe

¹⁰International Institute of Tropical Agriculture (IITA), Ghana

 $^{11}National$ University of Battambang, Fac. of Agriculture and Food Processing, Cambodia

¹²International Institute of Tropical Agriculture (IITA), Kenya

¹³University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany

¹⁴IFDC, United States

¹⁵NASA, Goddard Institute for Space Studies, United States

Crop modelling and simulation have become increasingly important tools in predicting the future climate change on crop production and exploring new agronomic management strategies/cropping systems to enhance resilience to climate change. However, the reliability of these models critically depends on how well the fundamental assumptions and concepts of the model are represented. The significant variability in model results observed in previous multi-model comparisons of monoculture systems is mostly due to a strong mismatch between models in terms of their assumptions. This leads to discrepancies in model outputs, even when they are run under the same condi-

Contact Address: Adam Muhammad Adam, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Garbenstr. 13, 70599 Stuttgart, Germany, e-mail: am.adam@uni-hohenheim.de
tions of climate, soil, and management practices.

Additionally, the complexities of intercropping systems regarding light, water, and nutrient sharing concepts cannot be compared to monoculture systems. Since models have varying levels of accuracy in the representation of fundamental processes for resource sharing concepts, and intercropping is a very complex system, we aim to examine how the existing models represent intercropping systems in their entirety, including their assumptions, concepts, equations, and parameters. Most of these assumptions are rarely explicitly described in scientific publications, and sometimes they are not immediately apparent in the model documentation from model developers and experts users perspective.

This poster will provide detailed description of intercropping models routines, scale of application in time and space and unbiased insight into the key strengths and weaknesses of the existing models in terms of intercropping capabilities. In addition, the poster will highlight areas that may need further improvement regarding intercropping modelling for above-ground and below-ground resource sharing.

Keywords: Comparing models assumptions, intercropping routines, model structures

Bearing the brunt: Gendered impacts of heat stress on agri-food systems

Pooja Kori, Ranjitha Puskur

International Rice Research Institute, Evidence module, CGIAR GENDER Platform, India

Extreme heat caused by climate change and human environmental exploitation has become one of the deadliest and costliest threats to global agri-food systems. Men and women have specific roles and responsibilities within agri-food systems, yet structural inequalities limit women's control and access to resources, information, and extention services. These inequalities shape the ways in which men and women experience, respond to, and are affected by heat stress. Despite this, a significant evidence gap exists in understanding the nuanced gendered impacts of extreme heat on women in agriculture. Adopting a gender and intersectional lens, this paper argues that gender-blind interventions fail to address the gendered impact of heat stress and further exacerbate gender inequalities in agri-food systems. Evidence suggests that women in agriculture, especially in regions like Asia and the Pacific, face significant challenges caused by extreme heat and societal norms. They endure long hours under the scorching sun without proper access to shade, cooling places, or adequate breaks for rest and hydration. These conditions, coupled with limited access to proper sanitation facilities and appropriate workwear, pose serious health risks, particularly for pregnant and elderly women. Additionally, women bear the burden of additional responsibilities such as caring for family members, ensuring food security, and managing the effects of reduced crop yields and food safety concerns caused by high temperatures.

The paper argues that these challenges are more pronounced among marginalised communities, particularly female-headed households, subsistence farmers, and wage labourers. The paper also explores the resilience and mitigation strategies employed by women farmers. Prioritising women's health and well-being is crucial to building resilient and sustainable agri-food systems. Comprehensive interventions targeting women's health, workplace environments, and social norms can aid in coping with higher temperatures. This paper argues for broadening of climate change adaptation discourse by highlighting gender inequalities in heat stress experiences and advocating for comprehensive approaches that prioritise building resilience in vulnerable populations and promoting gender equity in climate action.

Keywords: Agri-food systems, climate change, gender, gender-responsive adaptation strategies, heat stress

Contact Address: Pooja Kori, International Rice Research Institute, Evidence module, CGIAR GENDER Platform, 340/c school st saheed nagar, 751007 Bhubaneshwar, India, e-mail: p.kori@irri.org

Forecasting grain maize yield in sub-Saharan Africa: A hybrid modelling approach

Amit Kumar Srivastava¹, Krishnagopal Halder², Jan Timko³, Lily-Belle Sweet⁴, Manmeet Singh⁵, Thomas Gaiser⁶, Frank Ewert⁶, Radwa Elshawi³

¹Leibniz Center for Agricultural Landscape Research (ZALF), Germany

²Vidyasagar University, Dept. of Remote Sensing and GIS, India

³University of Tartu, Institute of Computer Science, Estonia

⁴*Helmholtz Centre for Environmental Research, Dept. of Computational Hydrosystems, Germany*

⁵University of Texas at Austin, United States

⁶University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany

The dual challenges of climate change and a burgeoning global population, projected to surpass 9 billion by the year 2030, present unprecedented hurdles for the agricultural sector. These challenges underscore the need for developing precise and timely crop yield forecast (CYF) models. To enhance CYF, various methodologies have been explored, ranging from process-based models (PBM) to data-driven statistical approaches. Process-based models' are hindered by uncertainties in structure, inputs, and parameters, exceeding observed yield variations over time/space, ehereas, Machine Learning (ML) models are often a black box needing explanations. Therefore, this paper delves into the transformative potential of hybrid model approach where we tried to use the outputs of PBM as features to improve the prediction accuracy of ML for maize yield predicitons across sub-Saharan Africa inclusing 54 countries. As input features into ML, the climate data was obtained from ERA5-Land consisting of a daily time series from 1981 to 2016 including solar radiation, precipitation, minimum and maximum temperature. Grain maize yield data from 1981-2016 were obtained from the PANGAEA (https://pangaea.de) database. The relevant soil parameters from African soil property maps (https://www.isric.org). We adopted time-based cross validation strategy, characterised by iterative training of the XGBoost model using twenty years of historical data. The results indicate an R² score of around 0.72 on the five-year forecast, along with MAE and RMSE values of 0.61 and 1.07 tons per hectare (t ha⁻¹) respectively under pure ML approach, however, the hybrid model approach indicated slightly better forecast with 4.1%, 5.0%, and 3.8% in R², MAE and RMSE respectively. We also moved beyond prediction and interpreted the outputs of our model approach using SHAP and force plots which provided key insights in explaining the yield forecast results (importance of variables by time). We found soil type and water stress factor as the most critical features in grain maize yield forecasting.

Keywords: Hybrid model, maize, sub-Saharan Africa, yield forecast

Contact Address: Amit Kumar Srivastava, Leibniz Center for Agricultural Landscape Research (ZALF), Eberswalder Str. 84, 15374 Müncheberg, Germany, e-mail: AmitKumar.Srivastava@zalf.de

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Non-timber forest products

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Are non-timber forest products (NTFPs) the alternatives to overcome sustainable development challenges in Africa?

Achille Assogbadjo

University of Abomey-Calavi, Lab. of Applied Ecology, Benin

The number of people affected by hunger in the world increased to up to 828 million in 2021, an increase of around 46 million compared to 2020 and 150 million since the appearance of the covid-19 pandemic. This paper combines the results from our research activities and literature review to highlight, the potential role Non-Timber Forest Products (NTFPs) could play to overcome sustainable development challenges in Africa. It has been found that, in the Sahelian region of Africa, 80% of the households' incomes are derived from NTFPs. Moreover, more than 80% of people in sub-Saharan Africa used directly NTFPs as drugs to treat illness. At country level, shea butter for instance, is Benin's third largest export product, with an estimated contribution to GDP of 1.23 %. In the country, support for honey production in the gazeted forests could generate a turnover of 80 million FCFA (140,000 US\$) / year. 1 ha of baobab (Adansonia digitata) established from 100 individual trees can annually sequester 72 t C equivalent at \pm 190 t CO₂ that can be sold at USD 7600 on the carbon market; produce 500 kg pulp estimated at USD 25000/year and + 150 L of seed oil/year also estimated at USD 25000/year. Based on the above, we assume that NTFPs can enhance livelihoods and resilience of smallholder farmers to climate change and at the same time help in mitigating climate change in sub Saharan Africa. It has been discussed in the paper the efforts to increase awareness on NTFPs health benefits, food and nutritional values, the utilisation of their products and the needs to create markets for healthy food products using technological improvement and innovation tools.

Keywords: Climate change mitigation, contribution to SDGs, livelihoods, NTFP

Contact Address: Achille Assogbadjo, University of Abomey-Calavi, Lab. of Applied Ecology, Abomey-Calavi, Benin, e-mail: assogbadjo@gmail.com

A review on the sustainable production of *Capparis* erythrocarpos: An economically important species for medicine and conservation

Seyiram Kumordzie¹, Wilfred Elegba²

¹Centre for Plant Medicine Research, Plant Development Dept., Ghana ²Ghana Atomic Energy Commission, Biotechnology and Nuclear Agriculture Research Institute, Ghana

Capparis erythrocarpos is an important medicinal plant possessing high efficacy in managing inflammatory conditions, such as pain, arthritis, and blurred vision. In Ghana, the plant grows in the grassy savannah and the thickets of coastal scrub zone. The plant's root bark, stem bark, and leaf extracts have exhibited pharmacological activities from phytochemicals, making them promising resources for anti-inflammatory and pain-relieving medicine. Previous studies have reported that the root bark of *C. erythrocarpos* contained alkaloids, reducing sugar, triterpenes, phytosterols, and saponins However, the propagation of *C. erythrocarpos* is limited by high seed dormancy, heterozygosity, and slow growth rate of seedlings. Moreover, the widespread use of the plant's roots for inflammation and arthritis medicine results in the uprooting of whole plants, posing a threat to the species' survival. This review provides a comprehensive overview of *C. erythrocarpos*, covering its uses, botanical description, taxonomy, distribution, availability, cultivation, phytochemistry, and economic value. Additionally, the review discusses the existing methods for propagating the plant and the significance of establishing commercial plantations through micropropagation or *in vitro* culture. In Ghana, plant tissue culture has been successfully applied for the micropropagation of planting materials of food crops and medicinal plants, therefore, developing in vitro protocols that promote the commercial cultivation of medicinal plants such as *C. erythrocarpos* is crucial to meet the increasing demands for plant medicine in Ghana and the sub-region. In addition, in vitro propagation protocols for C. erythrocarpos will ensure the conservation of this important medicinal plant. Critical aspects of *C. erythrocarpos*, which require further investigation to ensure its sustainable production and use, are also highlighted. This review underscores the importance of addressing the challenges facing *C. erythrocarpos* concerning its propagation and sustainable use for plant herbal medicine in Ghana and Africa.

Keywords: Conservation, medicinal plant, micropropagation

Contact Address: Wilfred Elegba, Ghana Atomic Energy Commission, Biotechnology and Nuclear Agriculture Research Institute, Box LG 80, Kwabenya, Ghana, e-mail: welegba@gmail.com

Pollen diversity and protein content in differentially degraded semi-arid landscapes in Kenya

Pamela Ochungo¹, Ruan Veldtman², Rahab Kinyanjui³, Elfatih M. Abdel-Rahman⁴, Michael Muturi⁴, Michael Lattorff⁴, Tobias Landmann⁴

¹Technical University of Kenya, School of Surveying and Spatial Science, Kenya

 ²Stellenbosch University, Dept. of Conservation Ecology and Entomology, South Africa
³National Museums of Kenya, Palynology and Palaeobotany Section, Earth Science Dept., Kenya

⁴International Centre of Insect Physiology and Ecology (icipe), Kenya

In Africa there is a scarcity of information on how plant species that can provide forage for honey bees vary across differentially structured landscapes, and what are the implications of such variabilities on colony integrity. This research presents new insights into the diversity and richness of pollen collected by Apis mellifera scutellata, a subspecies of the Western honey bee native to sub-Saharan Africa, at six study sites of different degradation levels within a semi-arid landscape in Kenya. Ten colonies were established at each site and land cover characteristics were extracted using fused Sentinel-1 and Sentinel-2 satellite imagery. The sites differed by the proportions of natural vegetation, cropland, grassland and hedges within each site. Bee bread was collected five times, with three colonies in each of the six sites repeatedly sampled during the period from May 2017 to November 2018. Pollen identification and protein analysis within the study sites were thereafter conducted to establish the linkage between landscape degradation levels and abundance and diversity of pollen. Out of 124 plant species identified, Terminalia spp., *Cleome* spp. and *Acacia* spp. were identified as the most abundant species. Moreover, species richness and diversity were highest in the two sites located in moderately degraded landscapes. Pollen protein content showed statistically significant differences across season rather than geographical location. This study demonstrated that landscape degradation negatively affected the diversity and richness of pollen collected by honey bees. Consequently, this helps our understanding of native honey bees' forage resource usage and plant species preferences in landscapes with varying degrees of degradation.

Keywords: *Apis mellifera*, honey bee nutrition, landscape degradation, natural habitats, Sentinel

Contact Address: Pamela Ochungo, Technical University of Kenya, School of Surveying and Spatial Science, Haile Selassie Avenue, 00600 Nairobi, Kenya, e-mail: pamochungo@gmail.com

The role of advisory services in the commercialisation of NTFPs from the Cerrado, Brazil

BINYAM ABAYNEH ADERA

University of Hohenheim, Germany

The Cerrado, the second biggest biome in Latin America, is an important savannah biome that is home to diverse and unique vegetation and wildlife. It has been facing large levels of deforestation with 50 % of the native vegetation cover already lost and converted to agricultural lands. There are some initiatives in promoting Non-Timber Forest Products (NTFPs) as they provide a potential solution to curb deforestation while raising the livelihood of the farmers in the area. It also creates economic, social and nutrition opportunities to the community. However, to sustainably maximise the benefits of the NTFPs, there is a potential space for agricultural advisory services to provide support in the production, processing, and commercialisation efforts of the products.

Using the Agricultural Knowledge and Innovation System (AKIS) and the agricultural valuechain framework, the study investigates the role of advisory services in the commercialisation of NTFPs in the Rio Pardo region of Brazil. The main objective of the study is to understand the current and potential role of advisory services in providing NTFPs related support in the study area, and their role as bridging institute between the various stakeholders. The study will also investigate the motivations and hinderances farmers face in accessing advise and the capacity of digital tools to be utilised.

The study makes use of mix-methods to provide a better understanding of the role of advisory services in the commercialisation efforts of NTFPs. Qualitative data is collected through interviews with up to 14 farmers and 22 key stakeholders that are composed of advisory service providers, NGOs, cooperatives, and local administrators. While the quantitative analysis is an assessment on the impact of advisory service compared with other important variables on (100) farmers income from NTFPs. Initial results of this ongoing study will be presented, and recommendations provided on how much agricultural advisory services are important in raising income from NTFPs, how they could be improved to strongly foster sustainable NTFP commercialisation and an understanding of the farmers readiness in using digital tools as advisory tools.

Keywords: Agricultural extension, natural resource management, NTFPs, rural development, sustainable economics development

Contact Address: Binyam Abayneh Adera, University of Hohenheim, Schwerzstrasse 1, 70599 Stuttgart, Germany, e-mail: binyam.abayneh.adera@gmail.com

Rights-based access for leaving no biodiverse area nor anyone behind: Deliberative protected-area councils in Amazônia

Marcelo Inacio da Cunha

German Institute of Development and Sustainability (IDOS), Environmental Governance and Transformation to Sustainability, Germany

The Kunming-Montreal Global Biodiversity Framework (KMGBF) aims to expand protected areas (PAs) worldwide, a significant step towards harmonising with nature by 2050. Target 3 of the KMGBF aims to protect 30 % of lands and waters by 2030. However, establishing PAs calls for considering rights-based conservation, particularly for Indigenous Peoples (IPs) and local communities (quilombolas) in the Brazilian Amazon.

Given the self-reported limitations of resource access by marginalised forest reliant rural dwellers as well as the lack of an enabling institutional environment for reconciling biodiversity conservation and traditional livelihoods in the Brazilian Amazon, the main questions herein are: If/how do institutions (re)shape resource access by traditional communities in PA? How can accessimplications be addressed or redressed?

Research focuses on the Trombetas River Biological Reserve (TRBR) and the Term of Compromise (TDC), a federal decree-based mechanism addressing conflicts between the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and traditional populations over resource access. TDC's institutionbased access implications on livelihood-relevant access to non-timber forest products (NTFPs) are analysed. Mixed methods applied included a guantitative socioeconomic survey (n=185) and qualitative interviews focusing on quilombola households (n=89), participant observation. An own analytical framework and model combing access theory, institutions and (collective) property rights scholarship are developed and applied. The TDC formalizes Brazil nut access but unintentionally restricts it, affecting traditional livelihoods. The exogenously enacted TDC (through ICMBio) creates a monopsony by formally restricting access to resources and markets of PAaffected quilombola communities, while overwriting institutionalized and internalised customary norms which already regulated such livelihood-relevant access. Evidence-based options for addressing and redressing TDC access restrictions affecting quilombola communities include (i) land tenure security by titling Território Quilombola, recognising collective land tenure claim partially overlapping with TRBR; (ii) resource access through inclusive governance per PA co-management by quilombolas; (iii) co-creating an enabling in-

Contact Address: Marcelo Inacio da Cunha, German Institute of Development and Sustainability (IDOS), Environmental Governance and Transformation to Sustainability, Tulpenfeld 6, 53113 Bonn, Germany, e-mail: marcelo.inaciodacunha@idos-research.de

stitutional environment for PA-affected rightsholders to voice complaints and co-decide on access limitations by institutionalizing grievance and redress mechanisms in contested PAs. By distilling institution, determinants and processes of access towards rights-based access by traditional communities and IPs, this research intends to inform multi-scalar environmental governance towards a social-ecologically sound implementation of KMGBF Target 3.

Keywords: Access, indigenous people, local communities, livelihoods, New Biodiversity Plan, non-wood forest products, place- and rights-based management, protected areas, resource use rights, social-ecological tradeoffs

Modeling the horizontal distribution of tree crown biomass using terrestrial laser scanning: A method for advancing the accuracy of forest biomass estimates and monitoring techniques

Muluken Nega Bazezew, Nils Griese, Lutz Fehrmann, Nils Nölke, Christoph Kleinn

Georg-August-Universität Göttingen, Forest Inventory and Remote Sensing, Germany

Accurate biomass estimation methods serve as a keystone for informed decisionmaking in forest monitoring and policy formulations. By providing reliable biomass estimates or carbon stocks, decision-makers can develop sustainable forest monitoring strategies and carbon sequestration initiatives, which is pivotal for maintaining ecological balance and safeguarding the long-term health of forests.

Crown biomass, which accounts for considerable share of total tree biomass, can be considered one of the key forest variables and may provide substantial benefits if quantified accurately. Tree crown biomass is rarely assessed, though, in forest monitoring, but when it is to be reported, conversion factors are commonly used for predicting crown biomass as a function of stem biomass. Further, in conventional methods, the predicted total biomass is sasigned exclusively to the stem position. In reality, however, crown biomass is spatially distributed over the entire crown projection area: so far, models describing this distribution are absent in the forestry literature. The conventional approach also does not take into account that forest biomass is a variable with continuous horizontal distribution over any plot or inventory area. This has been a bottleneck in matching remotely-sensed biomass predictors to a specific field plot inventory biomass; since remotely-sensed information offers continuous spatial pixel information across crown parts.

We investigated a new biomass modeling approach, the *Horizontal Biomass Distribution* (HBD), which serves to spatially depict crown biomass distribution over the crown projection area of trees. Here, crown biomass is modeled as a continuous distribution, which enables the spatial allocation of crown biomass as a function of horizontal distance from the tree stem. To develop HBD models, we considered empirical functions and terrestrial laser scanning (TLS)-derived tree metrics. Our approach was examined using TLS data from trees outside the forest in Goettingen, Germany.

Conversely, our approach expands the horizon for mapping biomass distributions with the highest possible accuracy. This research can also be extended to further applications beyond the scope of this study, such as if modeling biomass loss in partially damaged tree crowns, or modeling fuel loads and forest fire spreads may be of interest.

Keywords: Carbon sequestration, continuous distribution of crown biomass, spatial distribution of crown biomass, TLS point cloud

Contact Address: Muluken Nega Bazezew, Georg-August-Universität Göttingen, Forest Inventory and Remote Sensing, Büsgenweg 5, 37077 Goettingen, Germany, e-mail: mbazeze@uni-goettingen.de

Woody biomass trends in Rwanda, combining stock and land cover change assessments in forests, shrublands, and farmlands

VALENS UWIZEYIMANA, BART MUYS, BRUNO VERBIST

KU Leuven, Earth and Environmental Sciences, Belgium

Forests play a pivotal role in mitigating climate change and promoting socioeconomic prosperity and ecological stability in Rwanda. Nevertheless, the extensive extraction of biomass for cooking has engendered a heavy dependence on this resource, resulting in excessive harvesting, forest degradation, and biodiversity loss. This study aims to assess the current potential of wood biomass and its trends from 2015 to 2021, specifically focusing on changes in woody biomass stock and tree cover across three distinct land-use systems (forest, agroforestry, shrubland, and wooded savannah) in the Eastern province (EP) of Rwanda. A total of 1,429 plots were randomly distributed and inventoried within the three land-use systems (LUS). The inventory findings were subsequently compared to the national forest inventory conducted in 2015. Furthermore, estimates were made regarding changes in stock resulting from variations in volume and cover.

The results reveal that the combined current stock for all three LUS amounts to 5.9 million cubic meters. Among these, the forest LUS exhibited the highest stock of 2.5 million cubic meters. The estimated total stock changes due to cover change is 1.2 million cubic meters. Forest LUS demonstrates a substantial stock increase of 1.5 million cubic meters, as a direct consequence of afforestation initiatives aimed at achieving a 30 % forest cover target in the vision 2020. The total stock, influenced by fluctuation in volume within three distinct LUS, amounted to a decrease of 188,593 cubic meters. A decline was observed in both the forest and agroforestry LUSs, suggesting a significant reliance on biomass as a consequence of excessive tree extraction. The cumulative stock change resulting from both woody biomass stock change and tree cover change within three LUS amounted to 1 million cubic meters. Additionally, there is a decrease of 422,707 cubic meters in the agroforestry LUS. This study provides invaluable insights that can inform intervention activities and decision-making processes, fostering climate change adaptation, biodiversity conservation, and landscape restoration in the EP of Rwanda.

Keywords: Cover change, Eastern Province, land use, Rwanda, stock change, wood biomass

Contact Address: Valens Uwizeyimana, KU Leuven, Earth and Environmental Sciences, Celestijnenlaan 200e room03.231, 3000 Leuven, Belgium, e-mail: valens.uwizeyimana@kuleuven.be

Natural forests products for rural development and poverty alleviation in Sudan

Hanadi Mohamed Shawgi Gamal, Asma Elyas Mohamed Elzubair, Zeinab Ahmed Abdel Hameed

University of Khartoum, Fac. of Forestry; Forest Products and Industries, Sudan

Sudan is a country with highly diverse ecological zones. The rainfall varies from zero in the northern part to more than 1,200 mm in the southwestern part of the country resulting in in great variation in vegetation cover. Therefore, Sudan has diverse forest products, including wood and non-wood forest products. The vast majority of Sudan forests are situated in poor rural areas, where great number of populations live around the forests and considered as forest-dependent for livelihood, wood energy and on round timber for buildings. For instance, in Sinnar State, most of the populations live in the rural areas, depending upon forest products in their livelihoods. However, no information is available about the contribution of natural forests in provision of forest products for the rural population and their roles in poverty alleviation. Therefore, this study attempted to provide information on the contribution of forest products into income of the rural livelihood and economic development in Nowara Natural Forest, Sinnar State, Sudan. The research was relied on probability techniques for data collection from local community members in the study area using the simple random sampling techniques. With regards to the data collection methods, combination of primary and secondary sources of data was used. The secondary data was collected from various sources that include archives, records and annual reports of governmental institutions and non-governmental organisation's (NGOs), as well as results of previous studies from published papers and documents. While, primary data was collected mainly using household survey through structured questionnaire using open and closed questions in which both qualitative and quantitative data were deployed via face-to-face interviews. For this research, both qualitative and quantitative data were analysed using Statistical Package for Social Sciences software (SPSS) version 25.

The results revealed that the forest products have significant contribution in enhancing the income of the local communities which leads to poverty alleviation of the rural populations in the study area.

Keywords: Forest products, natural forest, poverty alleviation, Sudan

Contact Address: Hanadi Mohamed Shawgi Gamal, University of Khartoum, Fac. of Forestry; Forest Products and Industries, Alemarat Street 61, Khartoum, Sudan, e-mail: hanadishawgi1979@yahoo.com

Effect of domestication on the genotypical and phenotypical diversity of *Allanblackia parviflora* A. Chev in Ghana

MARIE KALOUSOVÁ, EDEN FASIKA HAILE, DENNIS KYEREH, BOHDAN LOJKA Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Czech Republic

Understanding the genetic and morphological diversity of *Allanblackia parviflora* in Ghana holds paramount significance, particularly in the context of its domestication for sustainable agricultural practices. textitA. parviflora, a tree species indigenous to rainforest zones of West Africa, exhibits considerable potential for economic development and ecological restoration. As interest grows in harnessing its valuable traits for commercial cultivation, comprehending the genetic and morphological variations within *A. parviflora* populations becomes imperative, as it is especially important for the local population due to production of edible oil. Despite the nutritional and socio-economic importance of this tree, it is still at the early stages of its domestication process.

The present study seeks to unravel the genetic and morphological diversity across *A. parviflora* populations in four ecological zones in Ghana, shedding light on traits relevant to domestication efforts. By elucidating these aspects, we aim to facilitate the informed domestication and utilisation of *A. parviflora*, thereby fostering economic prosperity and ecological resilience in the region.

The data and samples were collected across four ecological zones in Ghana, namely the Moist Semi-Deciduous North West (MSNW) zone, the Moist Evergreen (ME) zone, the Wet Evergreen (WE) zone and the Moist Semi-Deciduous Southeast (MSSE) zone, and in each zone we sampled trees from farms (cultivated) and from forest (wild). In total, seven fruit traits and six tree traits were used for evaluating morphological diversity, and 1091 SNP markers were developed by the DArT seq platform to assess the genetic diversity of the selected individuals.

The basic genetic diversity indices showed a rather low genetic diversity (observed heterozygosity ranged from 0.029 to 0.044) and low differentiation between populations (pairwise Fst between ecological zones ranged from 0.0013 to 0.0078), however the results from AMOVA showed significant variation between cultivated and wild individuals within each ecological zone. ANOVA of the morphological traits showed significant differences of some fruit traits (number of seeds per fruit and fruit weight) between ecological zones. The results imply that both ecological zones and farmers' selection have an influence on shaping the genetic and phenotypical diversity of *A. parviflora* in Ghana.

Keywords: Genetic diversity, morphological traits, Non-timber forest products, orphan crops, SNP markers

Contact Address: Marie Kalousová, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, 16500 Prague, Czech Republic, e-mail: marie.kalousova@gmail.com

Towards inclusive development: Forest landscape restoration impacts on Tchamba Prefecture communities, Togo

Chiara Thomas¹, Hamza Moluh Njoya², Kossi Hounkpati², Katharina Löhr², Michaela Haug¹

¹*Albert-Ludwigs-University of Freiburg, Inst. for Empirical Cultural Studies, Germany* ²*Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany*

In recent years, forest landscape restoration (FLR) projects have emerged as critical interventions for environmental conservation and sustainable land management. However, understanding their impact on local communities, particularly within diverse socio-economic contexts, is essential for effective implementation and community engagement. This study in Tchamba Prefecture, Togo, aims to examine the effects of FLR projects on local communities, focusing on socio-economic impacts and the interplay of the social and ecological dimensions of FLR. Employing a mixed-methods approach, I conducted focus group discussions and semi-structured interviews with villagers, NGO staff, and local government officials. By comparing communities with and without FLR projects, insights into differential impacts and context-specific approaches for sustainable outcomes were provided. Using the livelihood framework, key themes were identified, emphasising the role of social capital in motivating participation in FLR projects. Findings suggest positive perceptions of FLR projects among local communities, influenced by traditional ecological knowledge, cultural practices, and community-specific contexts. Gender and age differences were evident in participation, underscoring the importance of inclusive approaches tailored to diverse community needs. The study further highlights multiple socio-economic benefits of FLR initiatives, including improved agricultural productivity, education opportunities, health, and enhanced social cohesion. While limited to observational trends, the findings indicate promising prospects for FLR projects in enhancing local socio-economic conditions. This research contributes to a nuanced understanding of the relationship between local communities and FLR initiatives, emphasising the importance of context-specific approaches for sustainable outcomes. The implications extend to policymakers, farmer groups, donors, and local communities, facilitating informed decision-making and promoting inclusive and sustainable development pathways.

Keywords: Community perceptions, FLR projects, livelihoods, local context

Contact Address: Chiara Thomas, Albert-Ludwigs-University of Freiburg, Inst. for Empirical Cultural Studies, Turnseestraße 47, 79102 Freiburg, Germany, e-mail: chiara.thomas@students.uni-freiburg.de

Factors influencing tree use among small farmers of Gorkha district, Nepal: Livelihood perspective

Mohan Krishna Chowdry Avilineni¹, Boris Llamas Menchu¹, Mathew Gonzalo Tello Manzo¹, Pablo Canton Perez¹, Bohdan Lojka², Sanjeeb Bhattarai³, Abdelrahman Ali Ghazi Al-Salem¹

¹*University of Copenhagen, Dept. of Food and Resource Economics, Denmark*

²Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Dept. of Crop Sciences and Agroforestry, Czech Republic

³Tribhuvan University, Nepal, Institute of Forestry, Nepal

The study site, Gorkha, located in Nepal's mid-hills, is prone to natural disasters such as earthquakes, landslides, and droughts, posing challenges to the livelihoods of its inhabitants. Despite facing constraints such as limited land size, agroforestry systems remain a crucial source of income, contributing to 42% of total household income among leasehold users in the Gorkha district. To understand the factors influencing tree cultivation on farms in this region, we conducted a socio-economic survey among 13 households around Goganpani village, within Ajirkot Rural Municipality Ward 4. The findings reveal that households rely significantly on trees, crops, and livestock for their livelihoods. Factors such as ethnicity, farm size, crop yield, and number of livestock (expressed in tropical livestock units - TLU) play key roles in determining the proportion of dependence on various sources, including farmland, community forest, leasehold, or government-managed forest. Among the surveyed population, the Gurung ethnicity, with better access to education and larger farm sizes compared to Dalits and Tamangs, demonstrated higher levels of crop and animal production, leading to greater self-sufficiency. Staple crops such as finger millet and maize were widely cultivated, while tapioca was the least grown, resulting in a self-sufficiency period of only six months in a year, with households relying on the local market for the remainder. Trees grown by households were identified as culturally and ecologically significant species based on their Use Value Index (UVI) and Importance Value Index (IVI) values, respectively. Culturally important species such as Alnus nepalensis, Ficus semicordata var. semicordata, and Schima wallichii were found to be the most culturally and ecologically important. Additionally, the estimation of TLU underscored the importance of livestock in farm ecosystems and the need for fodder. Farmland accounted for 80% of the fodder, with the remaining 20% sourced from governmentmanaged, leasehold, and community forests. Despite the numerous benefits offered by tree-based agroforestry systems, conflicts with wildlife pose a challenge, as trees on farms attract animals and birds that may damage crops. This highlights the need for effective strategies to manage such conflicts while maximising the benefits of agroforestry practices in the region.

Keywords: Agroforestry, cultural and ecological importance, ethnicity, fodder

Contact Address: Mohan Krishna Chowdry Avilineni, University of Copenhagen, Dept. of Food and Resource Economics, Rolighedsvej 23, 1958 Copenhagen, Denmark, e-mail: mohanchowdry4@gmail.com

The impact of hurricanes on the carbon stock of the juvenile stages of succession in the tropical rainforest in the Caribbean part of Nicaragua

Lenka Ehrenbergerová¹, Zdeněk Patočka², Gabriel Zlámal¹, Vít Dvořák¹, Petr Maděra¹

¹*Mendel University in Brno, Dept. of Forest Botany, Dendrology and Geobiocoenology, Czech Republic*

²Mendel University in Brno, Dept. of Forest Management and Applied Geoinformatics, Czech Republic

Tropical rainforests significantly impact the global carbon cycle. In juvenile stages of succession, carbon stocks in living tree biomass rise quickly until the forests mature. However, disturbances cause structural changes, releasing stored carbon into the atmosphere. Hurricanes, common in the Caribbean, greatly affect Nicaraguan forests.

We studied the private nature reserve Greenfields, a lowland tropical forest ecosystem protected after Hurricane Joan completely destroyed the land cover in 1988. Hurricane Julia further damaged vegetation there again in 2022. This unique forest allowed us to research: A) Carbon sequestered in woody biomass 27 and 34 years post-Hurricane Joan; B) The decrease in living tree biomass carbon content caused by Hurricane Julia. We established 41 permanent circular research plots (25 m in diameter) in 2015. However, in 2022, we were able to restore 39 of them, and in 2024, due to the terrain's impassability after the hurricane, only 24 could be restored. We measured the position, DBH, and height of all trees (>10 cm DBH) and utilised three different allometric equations to calculate biomass.

The amount of carbon in aboveground live biomass was for Chave's pantropic equation: 83 ± 40 (2015); 90 ± 43 (2022); 35 ± 18 t ha⁻¹ (2024); for the Breugel Panama's equation for secondary forests: 81 ± 33 (2015); 88 ± 30.5 (2022), and 41 ± 18 t ha⁻¹ (2024), and the Segura Costa Rica's equation for humid rainforests: 158 ± 61 (2015); 171 ± 62 (2022) and 80 ± 35 t ha⁻¹ (2024). Between 2015 and 2022, the carbon quantity in dead trees was 10 ± 35 t ha⁻¹, whereas in 2024, two years after the hurricane, it was 45 ± 35 t ha⁻¹ (counted by Chave's equation). The findings reveal a considerable reduction in carbon stock within aboveground biomass following Hurricane Julia. During the succession the amount of living biomass is gradually increasing, as well as the amount of dead wood. Our findings suggest that hurricanes significantly influence the carbon dynamics in the forests of the Caribbean region of Nicaragua.

Keywords: Death wood, disturbance, private reserve, rainforest, tree biomass

Contact Address: Lenka Ehrenbergerová, Mendel University in Brno, Dept. of Forest Botany, Dendrology and Geobiocoenology, Zemedelska 1/1665, 613 00 Brno Sever, Czech Republic, e-mail: lenka.ehrenbergerova@mendelu.cz

Firewood and charcoal demand in sub-Saharan Africa: Assessing sustainability and trends

Fatma Bircan Bodur

University of Hohenheim, Agricultural Economics, Germany

Wood fuel remains a crucial energy source for household consumption in sub-Saharan Africa (SSA). It is considered a lower-ranking fuel compared to fossil fuels. Unlike the experiences of other developing countries/regions, SSA has not followed the trajectory of an energy transition over time. The persistence of wood fuel consumption has long been associated with the dire economic conditions and the low-income levels of the region. However, recent developments on the energy front are likely to impose new constraints on the unique development path on a global scale. Surging energy prices and the emphasis on sustainable renewable energy sources are expected to further delay the shift to modern fuels. Foremost, the rapid population growth compels the sub-Saharan countries to use more of their wood resources to meet the sharply increasing household energy demand. Furthermore, a greater pressure on wood resources is expected to come from escalating charcoal demand due to the population expansion in the urban centres. The challenges both on demand and supply sides entail urgency for the sustainable management of the region's forestry resources. Therefore, the wood fuel situation in SSA takes precedence, capturing the attention of both researchers and policy makers once more. In this regard, this paper presents a comprehensive review of both country-specific and regional research, examining the drivers of firewood and charcoal demand and the various options for their sustainable provision. It particularly focuses on the urban preference for charcoal and the obstacles hindering the establishment of well-functioning charcoal markets. The paper also highlights a shift in perspective, moving from viewing wood fuel solely as a commodity in short supply to recognising it as a renewable resource. Its long-term supply can be achieved by adhering to sustainable wood fuel extraction and consumption practices. Solutions, including agroforestry, decentralised management, and regulation, are discussed to ensure a reliable wood fuel supply that balances energy requirements and forest conservation.

Keywords: Charcoal, demand for wood fuel, sub-Saharan Africa, sustainability, wood fuel

Contact Address: Fatma Bircan Bodur, University of Hohenheim, Agricultural Economics, Franz liszt weg 7, 71083 Herrenberg, Germany, e-mail: fatma.bircanbodur@uni-hohenheim.de

Differences in planting methods on growth rates of *Calliandra calothyrsus* in ex-limestone mining areas

Tedi Yunanto¹, Muhammad Saepul Mina²

¹*Ministry of Energy and Mineral Resources, Bandung Polytechnic of Energy and Mining, Indonesia*

²PT Akarna Marindo, Mining, Indonesia

Ex-mining areas must undergo reclamation activities to improve environmental quality. The faster the species of plants grow and develop in the ex-mining area, the faster the process of restoring and improving the ecosystem of the ex-mining area. Differences in planting methods such as Direct-Seedling and the use of Planting Stock can cause differences in growth rates. Therefore, it is necessary to investigate the effect of different planting methods on growth rates in ex-mining areas. The research was carried out in a former limestone mining area with the species of *Calliandra calothyrsus*. The planting method used is Direct-Seedling and Planting Stock with 20 seeds each. Seedlings with planting stock are planted after 1 month from the nursery process (germination). The first measurement was carried out after 3 months of planting. The results showed that the mean height for Direct seedling was 15.9 cm with the minimum and maximum heights being 11.0 cm and 34.0 cm respectively. Meanwhile, the mean height of Planting Stock is 20.5 cm with the minimum and maximum heights being 13.0 cm and 32.0 cm respectively. The mean diameter for Planting Stock also shows a higher mean value when compared to Direct-Seedling, namely 0.45 mm compared to 0.25 mm respectively. The results of statistical analysis using the t-test showed significant differences in results between the two planting methods for both height (p = 0.007) and diameter (p = 0.000). Apart from that, the results of soil analysis show that the pH value tends to be high, namely an average pH = 8.14 as a result of limestone dust resulting from the crushing process. Planting Calliandra calothyrsus species using the planting stock method can be used for ex-mining reclamation activities compared to Direct Seedling. This also reduces the risk of seeds not germinating and being damaged/eaten by animals.

Keywords: *Calliandra calothyrsus,* direct seedling, mine reclamation, planting stock

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

Contextualisation of a biodiversity monitoring exercise in Lore Lindu National Park, Indonesia

Mary Louise Mulligan $^{1,3},$ Heiko Faust², I Nengah Surati Jaya³, Christoph Kleinn 1

¹University of Goettingen, Chair of Forest Inventory and Remote Sensing, Germany ²University of Goettingen, Dept. of Human Geography, Germany ³IPB University, Dept. of Forest Management, Indonesia

Well-designed long-term monitoring programmes are essential for effective governance of natural resources. They reveal the current state and changes within a target area, deepen our scientific understanding of the natural environment, and offer feedback on the success or failure of management decisions. Even more, they provide immense value and satisfaction to the lives of the people involved in the monitoring exercises and an opportunity to exemplify more just scientific practices. In this study, we showcase the experiences of the 44 teammates who participated in the Remeasurement of tree diversity plotsfieldwork campaign that took place from February 2023 to February 2024 in Lore Lindu National Park in Sulawesi, Indonesia as part of the establishment of a long-term monitoring system for the park under Forest Program III, a financial collaboration programme between the German Development Bank KfW and Indonesian government. While the team typically consisted of seven to ten teammates at any given time, the campaign employed a total of 10 national park staff, 8 students of Indonesian universities, 25 local workers, and one botanist. Of all 44 teammates, only one was non-Indonesian. As such, this campaign heavily emphasised learning from and enhancing local knowledge systems and supporting local research and capacity. We interviewed teammates informally in the field and distributed a questionnaire after its completion to contextualize the monitoring activities and identify impacts of the project work for those involved. Across all groups, this work engendered meaningful connections, taught valuable skills, imparted important knowledge, and lead to personal fulfilment and a sense of accomplishment. For national park staff, herbarium staff, and students, the field activities improved their ability to perform their usual tasks and cascaded into follow-up projects that are Indonesian-led. Local workers expressed that the work instilled an appreciation for the park's natural resources and an impetus to protect them. From these results, we believe the Remeasurement of tree diversity plotsfieldwork campaign was a success in this context, largely due to its emphasis on co-creation and local knowledge systems. We encourage such an approach for future projects to promote more just natural resource governance and exploration of nature.

Keywords: Contextualisation, Indonesia, local knowledge systems, long-term monitoring, Lore Lindu National Park

Contact Address: Mary Louise Mulligan, University of Goettingen, Chair of Forest Inventory and Remote Sensing, Buesgenweg 5, 37077 Goettingen, Germany, e-mail: mary.mulligan@uni-goettingen.de

Towards understanding the wildfire dynamics and hot spots intensity in the central province of Cameroon: Contribution of Google Earth Engine (GEE) and spatial statistics analysis

Kueshi Semanou Dahan, Stefan Sieber, Katharina Löhr

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

Human activities are increasingly contributing to natural resources degradation particularly forest resources nowadays. These activities weaken or destroy these ecosystems. The study, through the geospatial tools of remote sensing and machine learning, investigated and assessed wildfire events its intensity in central Cameroon (Yoko and Nanga-Oboko municipalities) from 2003 to 2023. The use of Google Earth Engine's (GEE) platform and spatial statistics techniques such as Moran's I spatial autocorrelation, Getis-Ord Gi* hot spots analysis made it possible to assess the most vulnerable or nonvulnerable areas of these municipalities. It shows a strong presence of fire intensities (49.5 ha to 2651.7 ha) with a density ranging from 0 to 10.89 active fires (n) per km². The trend is upward for burned areas, and slightly downward for active fires (Mann Kendall and Sen's Slop statistics test) while for anomalies, 3.5 ha and 2n more were observed. November and December, February, and March, are the most prone fire months. The entire study area was subject to a high intensity of fires with an average of 1629.70 ha burned monthly and 931.26 ha considering the entire data series (2003–2023). Hot spots and strong areas spatial correlation (Moran's I = 0.009081; Z-Score = 15.454067; and p < 0.001) are observed in areas with a high fire occurrence. Therefore, the fire intensity areas are dependent on the width of the area burned. Thus, the frequency of fire is influenced by the location of the sectors. It will then be necessary to investigate the existing relative contributing approaches to the reduction of fire intensity by the various actors: human activities involved in the landscape restoration of promoting the right approaches.

Keywords: Cameroon, Google Earth Engine, human activities, Moran's I spatial autocorrelation, wildfire intensity

Contact Address: Kueshi Semanou Dahan, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder straße 84, 15374 Müncheberg, Germany, e-mail: kueshisemanou.dahan@zalf.de

Impact of illegal mining and its implication for land reclamation in Amansie South district, Ghana

Samuel Asamoah

Goethe University Frankfurt, Inst. of Physical Geography & Centre for Interdisciplinary African Studies (ZIAF), Germany

The Amansie South district is an agrarian area in Ghana endowed with rich mineral resources and a natural environment, facing the devastation of illegal mining activities. Most of the rivers in the area are polluted coupled with large tracts of farms and arable lands that have also been degraded and unrehabilitated. The previous studies on land use change analysis conducted on the study region and other areas with similar challenges have not thoroughly analysed its implication for land reclamation. This case study, therefore, considered in detail the land use and land cover changes in the Amansie South of Ghana and their implication for land reclamation and the urgency to find a lasting solution to illegal mining using land use classifications of 1986, 2015 and 2024 produced with remote sensing techniques and GIS. The quantitative analysis revealed that mined land has expanded rapidly from a mere 0.2% in 1986 to over a third of the district's total land area by January 2024, mostly due to the escalating impact of illegal mining activities. Between 1986 and 2024, the region experienced a significant decrease in farmland-10,000 hectares from 72 % to 56 % of the total agricultural land. This rapid expansion of mining has significantly reduced the area's agricultural capacity, threatening local food security and the economy. Furthermore, the natural forest cover has also halved in less than a decade from 9,388 ha in 2015 to 4,776 ha in 2024 due to agricultural expansion and illegal mining. These findings clearly imply an urgent need for immediate and effective land reclamation strategies to restore and rehabilitate these areas for future agricultural use and ensure sustainable land use for coming generations

Keywords: Amansie South district, Ghana, illegal mining, implication, land reclamation, land use

Contact Address: Samuel Asamoah, Goethe University Frankfurt, Inst. of Physical Geography & Centre for Interdisciplinary African Studies (ZIAF), Altenhöferallee 1, 60438 Frankfurt am Main, Germany, e-mail: s.asamoah@stud.uni-frankfurt.de

Parameterisation and application of the forest model PICUS for Zagros forests of Kurdistan, Iran

Ahmad Valipour¹, Manouchehr Namiranian², Michael Maroschek³, Werner Rammer³, Manfred J. Lexer⁴

¹University of Kurdistan, Dept. of Forestry, Iran

²University of Tehran, Dept. of Forestry, Iran

³Technical University of Munich (TUM), Ecosystem Dynamics and Forest Management Group, Germany

⁴BOKU University, Inst. of Silviculture, Austria

The patch model PICUS v1.5 was used to simulate forest dynamics in northern Zagros forests in Kurdistan, Iran. The study aimed (1) to calibrate model parameters of population dynamics sub-models (growth, regeneration and death of trees) for the specific site and species (Lebanon oak, Gall oak and Persian oak), and (2) to simulate different management scenarios to evaluate the effect of intended management alternatives. Regarding the management influences of local people, three possible use concepts were defined: (1) pollarding in a typical regional Galazani system, (2) trees that have never been utilised under the Galazani system, and (3) formerly pollarded trees where pollarding had been stopped. Four management scenarios have been defined and simulated: (a) business as usual (MS1): in this scenario all relevant trees are pollarded and no regeneration is possible due to livestock browsing. Fuelwood demand met by collecting dead trees and cutting some live trees. (b) conservation scenario (MS2): according to the formal administrative policies, pollarding is abandoned and there is no browsing impact on regeneration. Tending actions are performed when the stem number and crown area surpass the determined thresholds. There is no cutting of live trees for fuelwood. (c) Alternative management scenario (MS3a): All trees >2 m height are pollarded. To support regeneration, every 10 years a fence with an area of 400 m² per hectare is established for a period of 30 years followed by overstory clearing to facilitate the growth of young trees. Tending actions and cuttings for reshaping diameter distribution are conducted considering the stem number thresholds and intended stands structures. (d) Alternative management scenario (MS3b): Utilisation, tending and fencing are conducted as in MS3a with more intensity. The results indicate that the 'business as usual' approach leads to forest degradation due to the absence of regeneration, aging trees, and continuous harvesting. In contrast, the conservation scenario enhances stand size structure and regeneration, but it does not prioritise needs of local communities, as no utilisation is permitted. The results from alternative management scenarios (MS3a and MS3b) are comparable. They enhance stand structure and promote regeneration, while also allowing local utilisation within the estimated renewability capacity of the forests.

Keywords: Forest modelling, PICUS, scenario analysis, traditional forest management, Zagros forests

Contact Address: Ahmad Valipour, University of Kurdistan, Dept. of Forestry, Sanandaj, Iran, e-mail: ahmadvalipour@uok.ac.ir

Cooperation and value-chain upgrade of NTFPs: Learning lessons for *Bactris guineensis* in Colombia

Mabel Tatiana Rojas Rueda, Ricardo Vargas-Carpintero, Athena Birkenberg, Regina Birner

University of Hohenheim, Germany

There is a growing interest in including Non-Timber Forest Products (NTFP) in bioeconomy strategies. The commercialisation of NTFPs has often been advocated as a strategy that can simultaneously support forest conservation and socio-economic development goals while facilitating livelihood diversification. The two primary strategies for bolstering rural communities' engagement in NTFP markets include the promotion of local-level value-added processing and setting partnerships among harvesters, civil society organizations, and private enterprises. However, despite the commercialization of NTFPs, the scope of value addition remains limited. This is the case of *Bactris guineensis*, considered the most important fruit-yielding native palm in the Caribbean region of Colombia. Although its multipurpose applications in diverse bioeconomy sectors have been identified, its potential remains underutilised. A key factor influencing NTFP processing and commercialisation is the level of cooperation and integration among direct and indirect value chain actors, which is heavily dependent on the governance arrangements and institutions that support them. Therefore, to determine which governance arrangements and institutions foster cooperation for greater value-added through processing and partnership development, the Institutional Analysis and Development (IAD) framework was integrated with value chain analysis. Value chain analysis highlights that value addition depends on access to resources and markets but does not fully explain how policies and institutions influence behaviours toward specific outcomes. The IAD framework addresses this gap by examining the institutional structure at each value chain link and its influence on actors' decisions in collective-action situations. By applying this adapted framework to established NTFP value chains in tropical and subtropical regions with a high degree of commercialisation, we aim to identify and compare success and failure factors regarding institutional arrangements and their influence on value addition, providing a blueprint for upgrading *B. guineensis*. This research is expected to confirm that NTFP value chains are governed by a bricolage of institutional arrangements that must recognize the complex, adaptive, and multi-level interplay between ecological, social, economic, and technological aspects and best fit context-specific conditions. Therefore, this framework aims to support decision-makers by identifying value-addition factors from an institutional perspective and integrating socio-ecological aspects that influence NTFP value chains in socio-biodiverse bioeconomies.

Keywords: Bioeconomy, commercialisation, cooperation, governance

Contact Address: Mabel Tatiana Rojas Rueda, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Walbrunnenstr. 2, 70599 Stuttgart, Germany, e-mail: mabel.rojasrueda@uni-hohenheim.de

Identifying positive deviance cases to improve forest landscape restoration and well-being of smallholder farmers In Togo, West Africa

Kossi Hounkpati 1,2 , Hamza Moluh Njoya 1 , Kossi Adjonou 2 , Kouami Kokou 2 , Stefan Sieber 1 , Katharina Löhr 1

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany

²University of Lomé, Forestry Research Laboratory, Climate Change Research Centre (CRCC), Togo

Over the past decade, Forest Landscape Restoration (FLR) has been increasingly recognised by the scientific community, governments and local populations for its potential to restore ecological integrity and improve human wellbeing in deforested or degraded landscapes. This long-term process of FLR includes different types of land use and restoration activities, from the promotion of assisted natural regeneration of forests to tree planting and agroforestry systems. However, until now, it still difficult to determine the real impact of these practices on the various dimensions of human well-being. Studies appear limited, while the living conditions of local populations, mainly smallholder farmers, remain precarious. Nevertheless, in the same supportive environment where most smallholder farmers face well-being challenges, some overcome these challenges and outperform their peers using creative and contextually adapted solutions. This study assesses the existence of such positive deviance practices among smallholder farmers in Togo. In the context of the three-dimensional framework of human well-being and aligning with the positive deviance approach, four dimensions of performance are measured: the material well-being of smallholders, their relational well-being, their subjective well-being and the diversification of the FLR practices adopted. Based on a survey of 494 smallholders in ten cantons of Tchamba Prefecture in Togo in 2022, the best performers are identified by comparing absolute performance with the performance that would be predicted given the smallholders' favourable environment. The difference is combined into a relative performance vector for each smallholder farmer, then used to calculate the Pareto optimal. As such, smallholder farmers are identified as being more competitive than their peers across all four dimensions and appear to be able to make trade-offs. In-depth qualitative interviews are then conducted with positive deviant smallholders to identify the reasons behind their outperformance. The objectives of this study are to identify the cases of positive de-

Contact Address: Kossi Hounkpati, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Eberswalder Straße 84, 15374 Müncheberg, Germany, e-mail: kossi.hounkpati@zalf.de

viance among smallholder farmers and to examine the reasons behind their better performance. The results will help to inform FLR strategies through implemented innovations, to guide specific policies for human well-being and to enhance performance in similar FLR contexts. Positive deviances are also meant for possible up and outscaling to support FLR effectiveness.

Keywords: Human well-being, impact of FLR, positive deviance, restoration, smallholder farmers, Togo

Landscape-level sustainable land use optimisation of Lake Chamo catchment, southern Ethiopia

Shibire Bekele Eshetu 1, Meselu Tegenie Mellaku 2, Marcos Lana 3, Stefan Sieber 1, Katharina Löhr 1

¹Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF), Sustainable Land Use in Developing Countries, Germany

²Norwegian University of Life Sciences (NMBU), Fac. of Environmental Sciences and Natural Resource Management (MINA), Norway

³Swedish University of Agricultural Sciences, Crop Production Ecology, Sweden

Forest Landscape Restoration (FLR) doesn't take place on degraded lands only. When implementing on agricultural mosaic landscape, it is crucial to investigate which option is economically feasible, environmentally viable and socially acceptable. This study analyses the optimal land use to maximise the economic benefit while the carbon storage potential of the land use systems and employment potential is not compromised. The study was conducted in the Lake Chamo catchment of Ethiopia as a widespread practice of cultivating crops on steep slopes is common in the catchment, resulting in diminished productivity and posing challenges to environmental sustainability. A total of 128 households were surveyed to estimate parameters of the model, profit per unit of land use, labour requirement per land use practice, and total land use of the existing land use system practices namely, annual crop, perennial crop, agroforestry, and woodlot. We also sampled 101 plots to estimate the carbon storage of the land uses. Linear programming was applied to optimise the land use profit in three alternative scenarios. Scenario one, focusing on commercialisation, aims to maximise profit constrained by total available land size. Scenario two, Policy-bound commercialisation, pursues the same objective as the first but incorporates land suitability classification based on the country's rural land regulations. The third scenario, policy and employment-bound commercialisation mirrored the objective of the first two but also included minimum employment requirement criteria. The optimisation aimed to maintain natural land cover while redistributing the land uses influenced by human activity. The result from scenario one, focusing solely on profit led to dedicating all land to agroforestry. However, considering ecological and social factors reduced annual and perennial cropland by 21 % and 2.7 % respectively, while increasing woodlot area by 26%. Among the different agroforestry practices that are found in the area, combining fruit trees with annual crops was found to optimise profit, labour and carbon balance. Promoting agroforestry-based FLR options on the landscape has great potential for success as it aligns with the community's main goal of maximising profits and can be readily embraced and expanded.

Keywords: Forest landscape restoration, linear-programming, optimisation, sustainability

Contact Address: Shibire Bekele Eshetu, Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF), Sustainable Land Use in Developing Countries, Eberswalder strasse 86, 15374 Müncheberg, Germany, e-mail: shibire-bekele.eshetu@zalf.de

Assessing the ecological effectiveness of community forests for forest conservation in Inle Lake watershed, Myanmar

Nan Shwe Yi

Georg-August-Universität Göttingen, Burckhardt-Inst., Tropical Silviculture and Forest Ecology, Germany

Community forestry is one of the most promising forest management practices for restoring degraded forests with the participation of local communities while also improving rural livelihoods. Since 1995, this practice has been introduced to Myanmar with the seventh highest deforestation rate worldwide. During 30 years of implementation, most of the research focuses only on the socio-economic aspects of Community Forests (CF), causing various constraints like limited scientific information for choosing locally adapted forest management practice. Most importantly, limited monitoring activities on forest conditions has restricted the efficiency and effectiveness of the community forestry practice. Therefore, this study aims to assess the ecological effectiveness of CFs for conserving forests in terms of species diversity and stand structure on the eastern side of Inle Lake watershed, southern Shan State, Myanmar. Vegetation surveys were conducted in a degraded forest, Maing-thout CF and surrounding natural forest in Inle Lake watershed from March to April in 2024. A total of 25 nested sample plots $(20 \times 20 \text{ m per plot})$ were laid out in each study site to collect the diameter at breast height, total height and other variables. As soil is one of the most important environmental factors influencing vegetative growth, physical and chemical soil properties were also assessed by collecting soil samples from different horizons in the study sites. Furthermore, as this CF is established mainly to reduce water scarcity, secondary information about water resources and the provision of other ecosystem services before and after the CF establishment was also collected. Diameter frequency distribution, diversity measures and other indices are applied to analyse the stand structure and species composition of community forest by comparing with those of other two study sites. Up until now, the study found that CF is likely to have greater structural composition from degraded forest and becomes more similar to the surrounding natural forests. Overall, the study will provide the assessment on the ecological effectiveness of CFs for restoring degraded forests, while improving scientific information to select appropriate silvicultural and forest management practices, aiming at sustainable forest conservation and better quality of life for indigenous communities.

Keywords: Community forests, species diversity, stand structure

Contact Address: Nan Shwe Yi, Georg-August-Universität Göttingen, Burckhardt-Inst., Tropical Silviculture and Forest Ecology, Albrecht-Thaer-Weg 12 A, 37075 Goettingen, Germany, e-mail: nan.shweyi@stud.uni-goettingen.de
Smallholder farmers' contribution toward forest landscape restoration: Evidence from Tchamba district, Togo

Hamza Moluh Njoya¹, Kossi Hounkpati¹, Kossi Adjonou², Kouami Kokou², Stefan Sieber¹, Katharina Löhr¹

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany

²University of Lomé, Forestry Research Laboratory, Climate Change Research Centre (CRCC), Togo

Forest and landscape restoration (FLR) has received significant attention over the past decade as a global initiative to combat forest and land degradation worldwide. Togo, a sub-Saharan African country, is actively involved in the FLR movement, which acknowledges smallholder rural farmers as crucial actors in achieving restoration goals at the local level. However, the restoration efforts of smallholder farmers in Togo remain unexplored, both at the individual and collective levels, hindering the ability to effectively inform the operationalisation of its FLR strategy and the implementation of planned or future restoration interventions. This research investigates restoration efforts across forest and agricultural landscapes, estimates the area of farmlands under restoration, and analyses the specific drivers and barriers to restoration. We applied a mixed-methods approach combining multivariate Tobit regression and Poisson models based on a 2023 household survey (N = 313 households) and focus group discussions (8) from Tchamba district, Togo. The findings reveal that, on average, households in Tchamba district restored 2.11 (+1.28) hectares, representing approximately 36.19% of the total household landholdings. Findings also suggest that farmers employ diverse land management strategies to achieve their livelihoods, food security, and ecological restoration goals. Additionally, spatially consolidated and tenure-secured land plots lead to higher restoration efforts, while women's restoration actions are hindered by inadequate access to land. Therefore, restoration policies should prioritise land-ownership security, minimise fragmentation, and promote gender-responsive interventions. Strong local leadership, benefits for fuelwood and non-timber forest products, secure rights, and balance between energy, climate change adaptation, and ecological goals were identified as critical drivers for collective resource restoration. These results can guide restoration programmes involving collective actions and their governance.

Keywords: Adoption, restoration challenges, restoration practices

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

Analysis of adoption factors of forest landscape restoration in DIANA region, Madagascar

Madeleine Maomou 1, Hamy Raharinaivo 1, Kossi Hounkpati 1, Martin $\rm Welp^2,$ Katharina Löhr 1

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

²Eberswalde University for Sustainable Development (HNEE), Socioeconomics and communication, Germany

Facing the increasing degradation of natural resources, Forest Landscape Restoration (FLR) has emerged as a pivotal in the global effort to counter environmental degradation and promote biodiversity, and human well-being. In this context, Madagascar has set a goal to restore 4 million hectares by 2030. However, although the success of FLR depends on its adoption by local communities, this aspect is still inadequately explored. Moreover, the factors underlying the successful adoption of FLR are under-documented. This study aims to I) Classify the different FLR practices that the communities have implemented, and II) Identify drivers that impact the adoption of FLR practices in Madagascar (DIANA region). Literature reviews, individual interviews, focus groups, and surveys of 492 households were used to accomplish this goal. Binary regression and description statistics were applied to the data processing. The result shows that 86,99% of the local population in the study area are farmers, with an average household size of 4 people and a monthly income of 785,561.4 ariary (equivalent to 166.17 euros). The types of FLR practices in the localities were categorised into forestry, transversal, and agricultural options, with most practices being indigenous to the region but promoted by the project in the localities except Ambolobozobe and Antsoha, which have not yet implemented a project. An additional practice such as composting was found to be a newly implemented practice in the locality of Sadjovato. Factors influencing adoption mostly include household income, with household characteristics crucial in determining FLR adoption. Access to training in agricultural ecology also emerged as a determining factor, and lack of water. these findings highlight the necessity for a specific approach to promote FLR adoption in these local communities, considering socioeconomic aspects and providing targeted training and support. Addressing these factors is essential for achieving FLR initiatives.

Keywords: Adoption, forest landscape restoration, indigenous practices

Contact Address: Madeleine Maomou, Leibniz Centre for Agricultural Landscape Research (ZALF), Sustainable Land Use in Developing Countries (SusLAND), dieffenchstrassse 32, 10967 Berlin, Germany, e-mail: maomoumadeleine142@gmail.com

Assessment of cooperatives' capacity gaps in forest management and capacity building activities to improve performances

Kebede Chaka 1 , Mitiku Agene 2

¹Oda-Shenen Charity and Development Org, Programme Management, Ethiopia ²SWER Bureau of Agriculture, Natural Sources and Food Security, Ethiopia

Ethiopia is gifted with abundant natural resources of adequate landmass, fertile soil, favourable climate, water, wildlife, and others. Many of its resources are not properly identified, well managed, and fully utilised. The community-based approaches to Natural Resources Management (NRM) in general, and Participatory Forest Management (PFM) in particular, have been evolving after recognising that the top-down approach impedes conserving natural resources effectively, and accessing the to be generated goods and services. That means local communities have been involved in participatory natural resources management arrangements for better conservation of natural resources. However, the achievements in improving natural resources management outcomes have been mixed, while some are successful, others are not. The main purpose of the current study is to assess capacity gaps of cooperatives in forest management and prioritize capacity building activities to improve livelihoods of farmers in a sustainable basis. The study was conducted in two regions, six zones and six woredas: three woredas (Gumay, Beddelle Zuria and Mattu) from three zones (Jimma, Buno Beddelle and I/B/A/Bor) of Oromia region; and three woredas (Gimbo, Amaya Zuria, and Kachi) from three zones (Kaffa, Konta and Dawuro) of south west Ethiopia region (SWEPR). And six farmers' cooperative unions, nine kebele administrations, and eleven primary farmers' cooperatives were targeted for the assessment. According to the study results, the visited primary cooperatives and cooperative unions have their own specific (internal) capacity gaps (human, material and systemic), and external systemic/institutional challenges to properly function and market their products (timber and non-timber forest products (NTFPs) like forest coffee, honey, spices, fruits and bamboo). The existing capacity gaps of the primary coops and coop unions vary from zone to zone and from woreda to woreda whereby specific and appropriate intervention activities are needed. Consequently, the study set capacity gaps filling intervention activities on which the up-coming project would focus and work. Thus, special attention has to be given to forest cooperatives' capacity gaps filling to properly manage the natural resources and ecosystems; so that, it can continue to provide the goods and services the population need in general and improve livelihoods of the farmers in particular.

Keywords: Cooperatives, forest, livelihoods, natural resources management, non-timber forest products, participatory forest management, sustainable basis

Contact Address: Kebede Chaka, Oda-Shenen Charity and Development Org, Programme Management, Woreda 08, 1000 Code 1251 Addis Ababa, Ethiopia, e-mail: keam.waeb@gmail.com

Long-term changes in land cover, floristics, and structure of Mpanga central forest reserve: Facts from remote sensing and observational plots and their relevance for forest ecology and management

Joseph Bahati

Banana Industrial Research and Development Centre, Uganda

Despite the importance of tropical forests for carbon storage and biodiversity conservation, they are threatened by degradation and deforestation. Monitoring of the remaining forests can help detect adverse anthropogenic disturbances and assess the magnitude of forest alteration. Few studies examine long-term changes in tropical forests. Using data from remote sensing (1990–2022) and plot inventories (1994–2023), we sought to examine longterm changes in land cover, floristics, structure and human activities in Mpanga Central Forest Reserve. Landsat TM and Landsat OLI satellite imagery datasets were accessed from usgs.com and processed in programming interface on the GEE platform. Inventory data (tree species, diameter, and height) were collected using 30 circular plots. Plot conditions (undergrowth, canopy cover, and dead wood) and human-induced disturbances were recorded. Remote sensing showed an increase in settlements and cultivated land, and a decline in natural forest and shrubland. Inventory data showed that tree species composition shifted due to a decline in relative abundance of dominant species. Species richness and structure (stem density, maximum height, basal area, and aboveground biomass) declined. Human activities like cutting of saplings and mature trees increased. Undergrowth density increased while canopy cover and dead wood declined. Tree species used for drum making showed disrupted population structures so their long-term survival is not guaranteed. These changes in land cover, floristics and structure affect ecosystem services and wildlife through reducing forest productivity and habitat availability. In order to recover the historical conditions, the forest could be restored through assisted natural regeneration and active restoration involving native species. The density of preferred tree species can be increased through enrichment planting within the forest. To reduce the pressure on the forest, domestication of preferred tree species through on-farm planting and farmer-managed natural regeneration need to be promoted in forest adjacent communities.

Keywords: Diversity and forest structure, forest degradation, repeated measures, species composition

Contact Address: Joseph Bahati, Banana Industrial Research and Development Centre, 26a Lumumba Avenue, 35747 Kampala, Uganda, e-mail: joeb2007b@gmail.com

Influence of spiritual norms and an exogenous income shock on forest management in Guatemala

Dominik Suri 1 , Jan Börner 2 , Sebastian Kube 1 , Karen López García 2

¹University of Bonn, Institute for Food and Resource Economics (ILR), Center for Economics and Neuroscience (CENs), Germany

²University of Bonn, Center for Development Research (ZEF), Inst. for Food and Resource Economics (ILR), Germany

Forests provide a variety of ecosystem services, including biodiversity conservation and climate change mitigation, which stand as some of the greatest challenges facing humanity. Thus, gaining insight into the drivers of and barriers to sustainable forest management is vital. Using a within-subject design resource extraction game, we investigate the behavioural impact of such possible drivers and potential barriers, namely the role of spiritual norms, communication and the occurrence of exogenous income shocks, such as the COVID-19 pandemic. To this end, we conducted a lab-inthe-field experiment involving 130 indigenous smallholder farmers in three regions in Guatemala, namely Totonicapán, Escuintla and Salamá. In groups of five, participants made individual decisions over a series of rounds. They allocated working hours between agricultural production activities to generate private income and extinguishing burning trees in a community forest to maintain ecosystem services. Our results indicate heterogeneity in forest management activities between Totonicapán and the other two regions, both in the absolute numbers of remaining trees at the end of our game and in the direction of the income shock. Compared to a scenario of open access, characterised by the absence of explicit institutions and rules, the introduction of an exogenous income shock intensifies the pressure on the community forest in Escuintla and Salamá. Surprisingly, the observed change in conservation efforts does not significantly differ compared to the scenario where the shock is absent. When reminding participants about local spiritual norms with regard to nature and forests, however, forest conservation significantly increases on average, even though the income shock is still present. Further incorporating the possibility of cheap talk significantly enhances conservation efforts, but only in Totonicapán. Our findings suggest that spiritual norms are an important institution for governing the commons, even in times of crisis. However, heterogeneity between regions of the same country can impact the drivers and barriers in the common understanding of forest management practices. This calls for tailored policy instruments to address the specific local context.

Keywords: Common-pool resources, community forest management, dynamic games, income shocks, lab-in-the-field experiments, spiritual norms

Contact Address: Dominik Suri, University of Bonn, Institute for Food and Resource Economics (ILR), Center for Economics and Neuroscience (CENs), Nussallee 21, 53115 Bonn, Germany, e-mail: dsuri@uni-bonn.de

Agribusiness in transition: Bridging forest conservation initiatives and agricultural productivity in the Gran Chaco, Cerrado and Amazon

Dominic Ahrens

Dresden University of Technology, Chair of Tropical Forestry, Germany

Agribusiness has traditionally seen forests as barriers to agricultural expansion, often converting them into agricultural land to boost production, without fully recognising the critical role forests play in agricultural productivity. This mindset, however, has led to increased environmental, regulatory, and reputational risks for the companies.

In response to these evolving dynamics, companies are implementing a range of initiatives aimed at promoting sustainable forest management within their production landscapes. These initiatives include reducing deforestation by tracing suppliers and the origin of raw materials, adopting regenerative agricultural practices to improve existing agricultural land, and launching reforestation projects to counteract deforestation. Yet, despite growing corporate sustainability efforts, scientific research in forestry and social sciences continues to focus on the detrimental socio-ecological effects of agribusiness on forest landscapes, with little emphasis on studying these forest governance initiatives aiming for a more sustainable production.

This study aims to fill that gap by conducting a detailed content analysis of sustainability reports from multinational agribusiness enterprises operating in Argentina's Gran Chaco, as well as in Brazil's Cerrado and Amazon, three Latin American deforestation hotspots. The study specifically examines the soy and beef sectors to understand their approach to forest governance. The analysis involves mapping and interpreting a) specific commitments each company has made towards forest governance b) the initiatives they have undertaken to meet these commitments c) the methods and key actors involved in implementing these initiatives, and d) the resulting synergies and tradeoffs related to sustainable development in agricultural landscapes.

By offering insights into corporate forest governance strategies, this study offers a fresh perspective on the role agribusinesses play in tackling environmental and social challenges. It also contributes to a more comprehensive understanding of how these strategies might pave the way for more sustainable practices within the agricultural sector.

Keywords: Deforestation, forest governance, forest-risk commodities, land use change, sustainability initiatives

Contact Address: Dominic Ahrens, Dresden University of Technology, Chair of Tropical Forestry, Pienner Straße 7, 01737 Tharandt, Germany, e-mail: dominic.ahrens@tu-dresden.de

Challenges and solutions for water security in an Andean region: Insights from Azuay district

Paola Montenegro-Díaz¹, Valeria Falla-Valdez², Casey Iwamoto³

¹University of Azuay, Vicerectorate of Research, TRACES, Ecuador

²Pontifical Catholic University of Peru, Section of Geography and Environment, Peru

³Mississippi State University, Dept. of Forestry, United States

Azuay district, situated in the Ecuadorian inter-Andean region, encompasses a mosaic of communities, small towns, and a mid-sized city dotted across valleys and mountain slopes. Here human activities are strongly linked to agriculture, grazing, and forestry. These economic activities put pressure on water quality and quantity, that is to say on water security, affecting the well-being of inhabitants. Further, strategies for assuring water security are still lacking. Therefore, Azuay can be a representative site for studying challenges for water security in the inter-Andean districts. By conducting a literature review, we identified the most studied pressures on water security in Azuay. Then, a systematic literature review was undertaken to identify worldwide solutions aimed at overcoming the pressures on water security identified in Azuay (from the first review). The most studied pressures were natural environment dynamics (20%), grazing and agriculture (62%), and those pressures impacted the water quality of rivers through nonpunctual exports of both natural and added pollutants. Other studies reported pressures of climate change (45%, i.e., extended droughts) on the water quantity, and water quantity effects on the water-related provisioning services of drinking, irrigation, and food production. Other studies reported consequences of urbanisation on the water quantity (38%) resulting in floods, and water quality (14%)in terms of access to sanitation and insufficient waste-water treatment. Hence, grazing and agriculture were human activities that contributed the most to water insecurity. Solutions need to be proposed. To provide water security and water-related services, we selected among the reviewed solutions. To overcome impacts on water quality due to grazing, agriculture, and forestry we proposed nature-based solutions such as streams/river forests and constructed wetlands, for water quantity we proposed to replicate Andean ancestral infrastructures which use soils and ponds as natural infrastructures for water storage. Combined solutions, such as public awareness, filtration tanks, ecological toilets, plus conventional water-treatment plants were proposed in certain towns and urban expansion areas to improve water quality. The pros and cons of all solutions were well-discussed. We integrated knowledge about pressures and solutions for assuring water security in inter-Andean districts and guided their future management.

Keywords: Andean communities, ecosystem services, green solutions, mitigation, water provisioning, water scarcity

Contact Address: Paola Montenegro-Díaz, University of Azuay, Vicerectorate of Research, TRACES, Cuenca, 010101 Cuenca, Ecuador, e-mail: pmontenegropos@uazuay.edu.ec

Ecosystem services and interactions of the local communities in southern Benin community conservation areas: Naglanou forest and Lake Toho

Yasmina Adebi¹, Laurent G. Houessou², Waliou A. Abiola³, Geoffroy Kake², Toussaint O. Lougbegnon⁴, Sinsin Brice¹

¹University of Abomey-Calavi, Lab of Applied Ecology, Benin

²University of Parakou, Biomonitoring and Research Unit Conservation of Protected Areas and Wildlife (UR-BiCAF), Benin

³University of Parakou, Lab. Integrated Production Systems Innovation, Benin

⁴National University of Agriculture of Porto-Novo (UNAP), School of Tropical Forestry (EForT), Benin

Understanding the interactions between locales communities and ecosystems is essential for a thorough assessment of ecosystem services provided and the sustainable management of ecosystems. This study aims to assess ecosystem services and the interaction of local populations with the biological resources of two Community Biodiversity Conservation Areas in Sud-Benin (ACCB), namely Naglanou Forest and Lake Toho. Data were collected from surveys of 110 households in 11 riverfront villages of the two ACCBs. Relative citation frequencies were used to determine the most prevalent plant and animal species in the provision of services to the public. Next, organ use values were calculated to identify the most commonly used organs in the two Community Biodiversity Conservation Areas. Finally, local communities' perceptions of biodiversity degradation factors were assessed using a principal component analysis and the Kruskall Wallis non-parametric test. The results showed a diversity of plant species (70%) and animal species (75%), as well as the importance of non-timber forest products (fungi (12. 82%), snails (30. 77%), honey (19. 23%) and turtles (7. (67 %)) for local populations. The organs most often removed are the bark (20. 21 %), leaves (39. 76%) and fruit (21. 38%) in plants followed by fat (26. 79%), skin (30. 65%), feet (16.84%) and bones (15.64%) in animals. Deforestation, agricultural expansion, wildfires and climate change are the main threats identified to biodiversity. The local population proposed solutions such as the establishment of firewalls (72%), intensification of agriculture with agro-ecological practices (43%), reforestation (56. 86 %) and awareness campaigns (51 %) related to ecosystem services relevant to the conservation of this natural environment. It is therefore essential to consider these guidelines from riverfront populations in the planning and implementation of conservation actions within the two Community Biodiversity Conservation Areas (ACCB).

Keywords: Ecosystem services, Lake Toho, local communities, Naglanou Forest

Contact Address: Yasmina Adebi, University of Abomey-Calavi, Lab of Applied Ecology, Cotonou, Benin, e-mail: yadebi@yahoo.fr

Sustainable livelihoods in recreation forest communities: A case study from Cambodia

Emerson Carias Padilla¹, Alessandra Giuliani¹, Tol Sokchea²

- ¹Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL, Switzerland
- ²*Regional Community Forestry Training Centre for Asia and the Pacific (RECOFTC), Cambodia*

This research delves into the intricate dynamics of recreation forest governance and management within one community in Siam Reap Province (northern Cambodia) and two communities in Kampong Thom Province (central Cambodia), with a specific focus on their role as livelihood sources. The study aimed to understand how these forest areas contribute to the economic sustenance of local residents and how governance structures influence their management. Through a comprehensive approach involving interviews, focus group discussions (FGDs), and participatory games, a total of 60 stakeholders, including Forest Administration Officers, Commune Councilors, Village Chiefs, and Recreation Forest Chiefs, were engaged.

Quantitative data, including descriptive statistics, shed light on the demographic and economic characteristics of the communities, providing context to understand their reliance on recreation forests for livelihoods. Results highlight diverse approaches to forest management and community engagement, with stakeholders prioritising activities such as ecotourism, livelihood support, and environmental conservation.

Stakeholder analysis revealed collaborative governance structures involving various actors, including district authorities, civil society organisations, and international partners, aimed at promoting sustainable forest management and community development. Challenges such as financial constraints, communication barriers, and governance issues were identified, alongside opportunities for leveraging governmental support and potential funding avenues.

In conclusion, this study underscores the vital role of recreation forests as livelihood sources for communities, emphasising the need for inclusive stakeholder engagement and contextually relevant approaches in promoting sustainable governance and management. By addressing identified challenges and capitalizing on opportunities, stakeholders can enhance the resilience and sustainability of forest communities, thereby ensuring the continued well-being of local residents and the conservation of natural resources.

Keywords: Community engagement, livelihoods, recreation forests

Contact Address: Emerson Carias Padilla, Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences HAFL, Langasse 85, 3052 Zollikofen, Switzerland, e-mail: carie1@bfh.ch

Women's engagement in forest landscape restoration (FLR) practices in Irodo watershed (DIANA region): Practices and challenges

Hamy Raharinaivo¹, Madeleine Maomou¹, Zo Hasina Rabemananjara², Harifidy Rakoto Ratsimba², Stefan Sieber¹, Katharina Löhr¹

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

²University of Antananarivo, Higher School of Agronomic Sciences, Madagascar

Forest Landscape Restoration (FLR) initiatives play a crucial role in enhancing ecosystem services, biodiversity conservation, and sustainable livelihoods. Women's involvement in FLR practices has gained increasing recognition due to their unique perspectives, knowledge, and roles in natural resource management. This study investigates the features of women implementing FLR practices in the Irodo Watershed (DIANA Region), focusing on the types of FLR practices they undertake, their resource management strategies, and the challenges they encounter. Despite the importance of women's involvement, limited research exists on their specific contributions and challenges in FLR, particularly in the Irodo Watershed. Through qualitative and quantitative mixed-methods research, this study uncovers a diverse array of FLR practices undertaken by women in the study area. A total of 159 women heads of household were investigated, and focus group discussions (FGDs) with women associations in 5 localities in the Irodo Watershed were carried out. These practices include agroforestry, tree planting and other land use system. These practices often combine traditional knowledge and community approaches, reflecting a holistic approach to landscape restoration. Despite their vital contributions, women implementing FLR practices face various challenges. Socio-economic constraints, limited access to land and resources, and genderbased inequalities hinder their full participation and empowerment in FLR initiatives. Addressing these challenges requires many approaches. These are capacity-building programs, gender-responsive approaches which are vital for promoting gender equality, enhancing women's access to resources, and fostering inclusive governance in FLR processes. Gender-responsive approaches that empower women as key stakeholders in FLR processes. Understanding women's roles in FLR is crucial for promoting gender equality, enhancing environmental outcomes, and fostering inclusive governance.

Keywords: Forest landscape restoration, land use, practices, women

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

Can cooperative membership foster compliance with European Union regulations? Evidence from cocoa farmers in Côte d'Ivoire

Hamza Moluh Njoya¹, Sofía Cristóbal Reyes², Alberic Hien Koumbo³, Constant Yves Adou Yao⁴, Stefan Sieber¹, Katharina Löhr¹

¹Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries, Germany

²Ghent University, Fac. of Bioscience Engineering, Belgium

³University Institute Of Abidjan, Faculty Of Economic And Social Sciences,

⁴Félix Houphouët-Boigny University, Switzer Centre of Scientific Research (CSRS), Côte d'Ivoire

Cocoa cultivation (*Theobroma cacao* L.) in Africa has long been associated with deforestation in humid tropical regions, as trees are often planted on newly cleared forest land. Côte d'Ivoire plays a significant role in global cocoa production, contributing significantly to the world's cocoa supply and holding a key position in the global cocoa industry. However, the economic significance of this industry is accompanied by environmental challenges, such as deforestation and child labour practices. In response, the European Union (EU) has implemented strict regulations to promote sustainable cocoa production practices. Despite Côte d'Ivoire's leadership in cocoa production, there are growing concerns about its ability to implement the necessary sustainability measures to meet these new EU standards. Agricultural cooperatives are places where farmers share information and experiences, allowing them to acquire new skills and best farming practices. While numerous studies have examined the importance of cooperatives in enhancing the adoption of improved farming technologies and land management practices, as well as the economic performance and welfare of smallholder farmers, limited research has explored their role in providing information, raising awareness, and facilitating adjustments in farming systems and practices to ensure compliance with EU new regulations among cocoa farmers. This study investigates the potential role of cooperative membership in facilitating compliance with EU regulations among cocoa farmers in Côte d'Ivoire. We collected data from 218 cocoa farmers in the centre-west and west of Côte d'Ivoire. We used propensity score matching to estimate the average effect. The results reveal that, on average, cocoa farmers in the study area have a propensity score of 0.261, suggesting a 26.1% probability of being cooperative members based on their observed characteristics. The impact of cooperative membership on

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

EU regulation awareness was positive across different matching methods: 0.193 (t=1.64) in the nearest neighbour matching, 0.363 (t=4.94) in the radius matching, and 0.303 (t=2.52) in the kernel-based matching. These results imply that cooperative membership improves cocoa farmers' awareness of EU regulations. These results can guide policymakers and stakeholders in promoting cooperative membership among cocoa farmers to enhance their awareness of EU regulations, ultimately leading to better compliance and market access.

Keywords: Cocoa farmers, compliance, cooperative, Côte d'Ivoire, deforestation, EU regulations

Family labour and farm practices among cocoa producing farmers in the coastal region of Ecuador

MALENA TORRES ULLOA^{1,2}, PATRICK VAN DAMME¹, VLADIMIR VERNER¹, OMAR RUIZ BARZOLA², RAMÓN ESPINEL², EDUARDO ÁLAVA², DIEGO PORTALANZA³ ¹Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Czech Republic ²Littoral High Polytechnic School (ESPOL), Ecuador

³Agrarian University of Ecuador, Fac. of Agricultural Sciences, Ecuador

Family farming systems (FFSs) are fundamental for promoting food security and sustainable development. In Ecuador they contribute by 60 % of food production and play an important role in generating exportable products such as cocoa. However, very little is still known about performance and sustainability of coastal region FFSs, as well as their influence on the local agricultural landscape and provision of ecosystem services Therefore, the study aimed to characterise FFSs within the agricultural association "15 de septiembre" located in the Vinces canton of Los Rios province, Ecuador's coastal region. A questionnaire was conducted among all 161 members of the association. Subsequently, data were classified based on cocoa-producing households with a majority labour force from family members, resulting in a subset of 100 questionnaires. Cash crop diversity in each farm was assessed using the Shannon diversity index. Using data analytics and exploratory analysis, the variable cocoa variety was employed as study factor, categorised into three groups: CCN-51, national, and a combination of both varieties. Relationships between variables were explored through scatter plots, and correlations were tested for statistical significance at a 5% level. Approximately 60% of the farms cultivated CCN-51, 25% cultivated national, and the rest (15%) cultivated both varieties. Farmers cultivating CCN-51 and both cocoa varieties exhibited the highest diversity in cash crops compared to those with only national. Additionally, those with both cocoa varieties and only national tended to use more organic fertilisers, whereas farmers cultivating CCN-51 tended to apply more chemical fertilisers. The external labor force is similar in the three groups; however, those with both cocoa varieties tended to hire less. Also, in the three groups, there are at least three family members working in cocoa activities. The findings show variations in farming practices and labour dynamics among FFSs with different cocoa varieties in the coastal region of Ecuador despite the non-correlation between the studied variables. These preliminary results will be contrasted with the farmers' perceptions of the benefits of cash crop diversification. Also, by using remote sensing techniques and the ECOSER protocol the provision of ecosystem services among the farms will be estimated.

Keywords: ECOSER, family farming, food security

Contact Address: Malena Torres Ulloa, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences, Kamýcká 129, 16500 Suchdol, Czech Republic, e-mail: torres_ulloa@ftz.czu.cz

Linking drivers of food insecurity and ecosystem services in Africa

Gregory Aryee¹, Idalina Dias Sardinha¹, Cristina Branquinho²

¹University of Lisbon, Lisbon School of Economics & Management, Portugal ²University of Lisbon, Center for Ecology, Evolution and Environmental Changes (cE3c), Portugal

Food insecurity is a multidimensional and intricate problem, known to have significant implications for individuals, communities, and countries worldwide. Out of all the continents in the world, Africa has become the continent that is experiencing this uncertainty the most. Food Security (FS) encompasses several aspects such as availability, accessibility, nutrient use, and supply system stability with time and, more recently, other obliges to governance/agency and sustainability. Understanding the relationship and interactions between FS and Ecosystem Services (ES) is fundamental to developing policies that promote long-term sustainable and secure food systems. A conceptual framework is presented, that examines interactions between food insecurity drivers and ecosystem change drivers and the combined influence on ES. Our review further introduces existing trade-offs between ES on account of agricultural intensification. Some existing strategies to promote sustainable agricultural production are then discussed. These strategies include climate-smart agriculture, sustainably managed land, and effective handling of water resources. In the end, the potential of Payment for Ecosystem Services (PES), being a suitable approach to ensuring these strategies are adopted, especially in African countries where sustainable financial incentives are currently non-existent, is discussed. In resume, this review aims to make a conceptual contribution to understanding how drivers of food insecurity influence drivers of ecosystem change and the impact of these influences on the ecosystem, as well as the changes in ecosystem services that is delivered to humans. This contribution will ensure that more sustainable approaches will be explored by researchers and implemented by policy leaders to solve both existing problems.

Keywords: Climate change adaptation, food security, payment for ecosystem services, smallholder farmers, sustainable agriculture intensification

Contact Address: Gregory Aryee, University of Lisbon, Lisbon School of Economics & Management, Rua norte junior 121, 1950-206 Lisbon, Portugal, e-mail: rhystika200@gmail.com

Community-based fire management lessons learned from two provinces in Cambodia's Tonle Sap Biosphere Reserve

FIONA WEIRAUCH¹, MÉLANIE FEURER¹, TOL SOKCHEA²

¹Bern University of Applied Sciences, International Agriculture, Switzerland

²*Regional Community Forestry Training Centre for Asia and the Pacific (RECOFTC), Cambodia*

Globally wildfire occurrences are increasing due to anthropogenic changes in climate and land use in recent decades. Cambodia experiences the highest number of fires per area in Southeast Asia, coupled with an ongoing rapid deforestation rate this significantly impacts the flooded forest area of the Tonle Sap Biosphere Reserve (TSBR) and consequentially the livelihoods of the local communities. Community-based fire management (CBFiM) is an approach that substantially involves communities in developing and implementing land and forest management to prevent and control fires. The objective of the study is to understand opportunities and constraints affecting the implementation of CBFiM and the knowledge, attitude and practices present in the target area. This study is part of the Our Tonle Sap project that aims to enhance the management and restoration of critical habitats to facilitate resilience against environmental change. A participatory research approach was utilised in five community fisheries in the transition and buffer zone of the TSBR in Pursat and Siem Reap province. Data was collected through key informant interviews, focus group discussions and a household survey (n=80). The sample frame of the study included CFi members and villagers living in selected CFi. The results show that there is no correlation regarding CFi membership and knowledge, attitude and practices in connection with fire management behaviours. However, CFi members are more knowledgeable regarding CB-FiM. An obstacle is the lack of knowledge on ignition sources and disconnect between human-made fires and their impact on the community. The attitude towards CBFiM approaches is favourable within the communities. Practicing fire-related activities is not significantly linked to being more knowledgeable on fire making and extinguishing behaviours. A lack of incentives and adequate enforcement of the law are limiting factors on the efforts to reduce fire incidents. This study shows the potential of CBFiM in the TSBR. It concludes that, additionally to enhancing dissemination on the topics: fire prevention, CBFiM and flooded forest fires and their impacts, efforts regarding livelihood activities are needed. Enhanced cooperation between stakeholders will ensure sustainability. Utilized as a reference value this study can generate meaningful insight into the sustainability of CBFiM approaches.

Keywords: Cambodia, community-based fire management, flooded forest, natural resource management, Tonle Sap Biosphere Reserve

Contact Address: Fiona Weirauch, Bern University of Applied Sciences, International Agriculture, Jonas-Furrer-Str. 74, 8400 Winterthur, Switzerland, e-mail: fiona.weirauch@gmx.ch

Rethinking reforestation: Countering native tree narratives in the Philippines

Christopher Klapperich

Rachel Carson Center for Environment and Society, LMU Munich, Institute for Social and Cultural Anthropology, Germany

During the last centuries, Philippine forests have been heavily transformed as most of the old-growth forests of the archipelago have been cut down by Spanish, American, and, subsequently, Philippine authorities. In the last decade, the question of how to reforest the Philippine forest landscapes has become more relevant for many people in rural areas who are vulnerable to climate change and intensifying extreme weather events.

After experimenting with different native and exotic tree species while focusing on easy and fast growth during the U.S. colonisation, most Philippine reforestation projects in the 20th and 21st centuries have relied on a small diversity of exotic tree species. In contrast, the over 3.600 native tree species have not only been neglected but have also been described throughout my research by the exact opposite attributes: slow-growing and complex. Such generalisations can be analysed as environmental narratives showing how environmental knowledge and social/political order are mutually dependent. As these environmental narratives are still prevalent and, thus, continuously shape reforestation efforts, more and more voices from scientists and civil society started questioning the government's approach by asking: "Is the gov't reforestation programme planting the right trees?".

Based on my ethnographic material of eleven months of fieldwork in which I interviewed environmental authorities, scientists, and civil society groups, I will show how reforestation discourses and practices have been shaped by environmental narratives that are linked to colonial forest management and specific resource perspectives. At the same time, I highlight different strategies of scientists and civil society groups advocating for native trees, for example by promoting agroecology. To make the Philippine forest landscape more sustainable and resilient, it is crucial to understand the strategies of informal networks of scientists and civil society groups that are already contributing to the transformation of the Philippines' future forests.

Keywords: Agroecology, environmental narratives, native trees, Philippines, reforestation

Contact Address: Christopher Klapperich, Rachel Carson Center for Environment and Society, LMU Munich, Institute for Social and Cultural Anthropology, München, Germany, e-mail: christopher.klapperich@rcc.lmu.de

Microcredit dynamics and gender empowerment in Kampong Thom community forestry

JEREMIE GILLIERON¹, ALESSANDRA GIULIANI¹, TOL SOKCHEA²

¹Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Switzerland

²*Regional Community Forestry Training Centre for Asia and the Pacific (RECOFTC), Cambodia*

The study is situated within the historical and socio-economic context of Cambodia, where microcredit has emerged as a significant tool for rural development. Microfinance institutions (MFIs) have played a crucial role in providing financial services to the underserved rural population, particularly in areas like Kampong Thom province. These initiatives date back to the early 1990s, following the end of decades-long conflict and political instability, aiming to address widespread poverty and the lack of access to formal banking services prevalent in rural areas.

The Credit Scheme examined in this study represents one such microcredit programme implemented in Kampong Thom province. It aims to provide financial assistance to households engaged in community forestry activities, with overarching goals of poverty alleviation and conservation. By exploring the historical evolution of microcredit in Cambodia and its relevance to rural development, this research seeks to contextualize the Credit Scheme within broader microfinance initiatives.

Utilizing a mixed-methods approach, the study combines quantitative surveys and qualitative interviews to analyse the scheme's impacts on livelihoods, gender dynamics, and conservation efforts. Through structured surveys administered to beneficiaries and in-depth interviews with stakeholders, the research aims to provide a comprehensive understanding of the scheme's multifaceted implications.

Findings reveal both benefits and challenges associated with the Credit Scheme. While it serves as a vital financial resource for households engaged in community forestry, a significant portion of allocated funds tends to be directed towards non-productive ends, posing obstacles to effective poverty alleviation. Gender dynamics also play a crucial role, with women often experiencing economic dependency despite recognising the scheme's benefits.

In light of these findings, the study advocates for targeted policies and initiatives aimed at empowering women economically, fostering gender equality, and promoting sustainable conservation practices. It underscores the need for nuanced policy formulations that balance poverty alleviation with conservation objectives, thereby contributing to the discourse on microfinance's intricate impacts and informing inclusive development strategies in Cambodia's rural areas.

Keywords: Cambodia, community forestry, microfinance, over-indebtedness, poverty alleviation, women

Contact Address: Jeremie Gillieron, Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences (HAFL), Rue charles-Giron 27, 1203 Geneva, Switzerland, e-mail: jeremie.gillieron@gmail.com

How do alternative livelihood activities impact poverty reduction in forest-based households? Evidence from Omo Biosphere Reserve, Nigeria

Kazeem Akanni Jimoh

Czech University of Life Sciences, Dept. of Economics and Development, Czech Republic

In recent times, the effect of socio environmental threats on biodiversity has emerged as a central issue in ecological and environmental sciences. Efforts are being made by policymakers, donors, and experts to link sustainable development with biodiversity conservation through promoting alternative livelihood strategies. In 2014, UNESCO/ Korean International Cooperation Agency (KOICA) funded the project "Green Economy in Biosphere Reserves (GEBR): A Means To Poverty Reduction, Biodiversity Conservation and Sustainable Development in Sub-Saharan Africa" which was carried out in selected Biosphere Reserves in three African countries namely Ghana, Nigeria and Tanzania with the aim of reducing poverty among youth and women, as well as conserving biodiversity through a well-developed and managed green businesses. It is therefore imperative to explore the effect of this intervention on the livelihood of the benefiting households. This study will empirically examine the effect of alternative livelihood income activities on the poverty status and welfare of rural communities in one of the selected biosphere reserve, i.e Omo Biosphere Reserve in Nigeria. Sustainable livelihood approach will be adopted for this study. Data will be collected through administration of well-structured questionnaires and focused group discussion from beneficiaries of the project. The target respondents are the beneficiaries and nonbeneficiaries of the GEBR project. A multistage sampling technique will be employed. The first stage will involve random selection of four beneficiary communities. In the second stage, the households will be stratified based on those who benefitted and those who did not. In total, 500 households will be sampled. GEBR beneficiaries will be oversampled in order to have the sufficient observations to make inferences. Data will be analysed using Foster, Greer and Thorbecke (FGT) poverty model, Propensity Score Matching Model (PSM) and Endogenous Switching Regression Model (ESR). At the end of the study, the poverty status (severity and extent) as well as the impact of GEBR project on the livelihood of the benefiting household would have been established.

Keywords: Alternative livelihood activities, deforestation, green economy

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

Exploring support for ecosystem cooperatives: Assessing environmental and cooperative values

Rishabh Mahendra, Harvey James

University of Missouri, Division of Applied Social Sciences, United States

This research investigates a novel approach to ecosystem restoration and conservation: collective efforts in the form of cooperative organisations (for example, agricultural cooperatives). We explore the characteristics of individuals who might be drawn to participate in these organisations. Existing conservation efforts often face limitations due to fragmented involvement and high costs, among other reasons, hindering their effectiveness. Cooperatives, that are a collective action organisational structure where individuals pool resources to achieve shared goals, present a promising solution. However, it is essential to study the willingness and profiles of potential participants in these organisations, specifically focused on ecosystem preservation, which remains unclear and thus creates a critical research gap. This research aims to identify the demographic and attitudinal characteristics of individuals willing to engage in such collaborative efforts by assessing their environmental and cooperative values as well as their altruistic traits. We hypothesise that a preference for both environmental and cooperative values is crucial for people's participation in such efforts, as well as an altruistic outlook. The objectives include examining the correlation between these values, determining the percentage of individuals exhibiting high levels of these values, and exploring the statistical connection between high values and characteristics such as occupation, economic status, and political inclination. The conceptual framework categorises individuals based on their environmental and cooperative values, suggesting that those with high levels are more likely to participate in collaborative ecosystem conservation activities. The study employs purposeful sampling for a values assessment survey, ensuring diverse participant representation. A mixed-methods approach gathers quantitative data through Likert-scale questions and qualitative data through interviews. The significance lies in understanding the values driving individuals, validating the concept of collaborative ecosystem conservation through cooperative organisations, and informing targeted interventions for sustainable behaviours. The study's outcomes provide implications for policymakers, educators, and advocates to develop strategies leveraging shared motivations for effective conservation initiatives and unified responses to societal and environmental challenges.

Keywords: Conservation, cooperative organisations, eco-coops, ecosystem restoration, environmental values, mixed-methods research, policy interventions, sustainability

Contact Address: Rishabh Mahendra, University of Missouri, Division of Applied Social Sciences, 1133 Ashland Road, Apt. 701, 65201 Columbia, United States, e-mail: rmdhd@umsystem.edu

Leveraging citizen science for enhanced forest fire management in tropical and subtropical forestry

The Trung Hoang¹, Mortimer Müller¹, Quang Bao Tran², Florian Heigl³, Harald Vacik¹

¹BOKU University, Institute of Silviculture, Austria ²Ministry of Agriculture and Rural Development, Dept. of Forestry, Vietnam ³BOKU University, Institute of Zoology, Austria

In recent decades, forest fires in tropical and subtropical regions have become increasingly frequent and severe, resulting in major ecological losses, affecting rural livelihoods, and claiming the lives of forest rangers who fight these fires. Climate change and land-use changes, such as logging and agricultural expansion, drive this escalation. One approach to study forest fires involves a citizen scientists to collect and monitor forest fuel loads and fire events in real-time with the spotFIRE app in Hue province, a fire-prone region in Vietnam. This allows to evaluate the potential of forest fire risk-related observations through citizen scientists for improving fire risk assessments and management strategies. The first version of the spotFIRE app, released in 2023, enables and engages citizens in forest fire management by allowing them to document fire events and forest fuel loads. In order to assess the potential value of the forest fuel loads and fire data observations, we performed pilot tests at the same spots by thirty-two participants from different groups, including volunteers, rangers, and forest owners using the spotFIRE app. According to preliminary results, citizens are capable of estimating forest fuel and fire data with relatively high accuracy. The parameters examined include fuel conditions, surface vegetation types, continuity of the flammable surface vegetation, continuity of large woody debris, fuel ladders, and ignition likelihood. The accuracy and quality of the data collected support forest fire prevention activities, thereby contributing to the modelling of fire hazards and the assessment of ecosystem services. In case multiple users report a significant accumulation of dry leaves and fallen branches in a particular forest area, those data can help identify it as a high-risk zone. This allows for timely actions such as targeted controlled burns, silvicultural measures or increasing patrols to prevent fires. Furthermore, the expected results include the establishment of a robust and verified community-driven model for reducing forest fire risks, the implementation of improved approaches for ecosystem management. Last but not least the project should foster greater public engagement in forest fire prevention.

Keywords: Citizen science, forest fires, spotFIRE, wildfires

Contact Address: The Trung Hoang, BOKU University, Institute of Silviculture, Peter-Jordan-Straße 82/ii, 1190 Vienna, Austria, e-mail: trung.hoang@boku.ac.at

Maintaining and restoring sustainable food systems on indigenous people's lands through social forestry in Indonesia

Mirna Asnur

Environmental Knowledge Development Institute of Aceh, Forest Governance, Indonesia

Over 1.6 billion people worldwide – or about 20% of the world's total population in 2023 rely on forest resources for their livelihoods, primarily in securing water, food and fuel. Some 70 million of global population -including many Indigenous communities- even define forests as their home. In line with this, decentralisation of forest management has become the core of a rightsbased approach that guarantees community access to forest resources, which has led to the Community-based Forestry (CBF) regimes, particularly in the Global South. CBF has been identified as a way to strengthen the rights of local communities to actively participate and gain multiple social and environmental co-benefits from forest management, such as poverty alleviation and reduced deforestation. In Indonesia, this CBF management mainly known as Social Forestry (SF) scheme. It is defined as a system of sustainable forest management implemented in state forest areas, or forest rights or customary forests implemented by local communities or customary law communities as the main actors to improve their welfare, environmental balance, and social cultural dynamics in the form of village forests, community forests, community plantation forests, customary forests, and forestry partnerships. Through a set of field observation, in-depth interviews and focus group discussion involving important customary institutions and direct forest users, this research will focuses on studying how indigenous peoples, as one of the vulnerable groups, can take advantage of the SF scheme, in particular to maintain and restoring sustainable food systems on the customary land. This research address how the indigenous people using their local values that have been embedded in their daily life for generations, from the rules to prohibitions in their traditional agriculture to secure the land, air, water, soil and culturally important plant, animal and fungi species that have sustained Indigenous peoples over thousands of years. All parts of this indigenous food systems are inseparable and ideally function in healthy interdependent relationships to transfer energy through the present day agriculture based economy that contribute in strengthening the sustainable food system.

Keywords: Community development, community-based forestry

Contact Address: Mirna Asnur, Environmental Knowledge Development Institute of Aceh, Forest Governance, PJKA II Num.10, Ateuk Pahlawan, Baiturrahman, 23241 Banda Aceh, Indonesia, e-mail: mirnaasnur@gmail.com

Local communities' preferences and willingness to contribute communal labour towards rehabilitating small-scale mined community lands: A choice experiment approach

Ferdinand Adu-Baffour

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

This study aims to investigate the willingness of rural communities to participate in voluntary labour for the restoration of degraded, contaminated, and abandoned land resulting from illegal Artisanal and Small-Scale Mining (ASM) activities. A Discrete Choice Experiment (DCE) was conducted to assess the preferences of respondents regarding various attributes of land rehabilitation, such as physical reconstruction, phytoremediation, post-restoration revegetation, time cost, and labor-hour commitments.

The study surveyed 320 households from five active mining communities in the Amansie West District of the Ashanti region in Ghana, where mining activities coexist with agriculture and forestry. Results indicated a strong preference for physical land reconstruction, despite its higher cost compared to other methods. Although the use of specialised plant species for phytoremediation was also supported by the communities, they preferred to allocate only 50 % of the reclaimed land to this method, reserving the rest for farming food or cash crops.

The preference for limited phytoremediation, along with the heterogeneity among respondents, underscores the community's lack of awareness regarding the health risks associated with heavy metal-contaminated soils. The presence of dense vegetation cover, which promotes biodiversity and ecosystem services, was another preferred attribute with a random choice effect. Furthermore, the study found that the waiting time for the safe reuse of restored land influenced decision-making, particularly when it exceeded 20 years. These findings suggest the need for tailored approaches to engage rural community members in land rehabilitation projects that prioritise physical reconstruction, education on health implications of ASM activities, and sustainable remediation strategies. Additionally, emphasising the time required for successful restoration is essential for community buy-in and long-term project success.

Keywords: Community labour, discrete choice experiment, illegal artisanal and small-scale mining, land degradation, phytoremediation

Contact Address: Ferdinand Adu-Baffour, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Wollsgrasweg, 70599 Stuttgart, Germany, e-mail: ferdinand.adubaffour@uni-hohenheim.de

Short or long plantation rotation? Analysis of economic efficiency of *Acacia* timber production in Vietnam

Hien Vo Thi Hai¹, Tham La Thi²

¹Vietnam National University of Forestry, Finance and Accounting, Vietnam ²VNU University of Economics and Business, Vietnam National University, Economics for Social Issues, Vietnam

Attributed to the growing global demand for timber products and considerable foreign direct investments, the wood-based product manufacturing and export sector in Vietnam has developed rapidly. The Vietnamese forest-based products are currently exported to over 120 countries, making Vietnam the fourth largest global furniture exporter and the largest woodchip exporter. Plantation forests play an important role in sustaining the material supply for the country's wood-based sector, especially after the restriction of timber harvests from natural forests in 2014. Approximately half of the plantation area is currently under the management of small-scale producers with *Acacia auriculiformis* × *Acacia mangium* hybrids being the most popular cultivated species. Nevertheless, up to 80 % of plantation wood is used for low-value woodchip production. To meet the increasing domestic timber demand and stimulate higher value uses of plantation wood, the Vietnamese government has introduced several policies, such as land tenure or long rotation timber plantation promotion. A comprehensive analysis of this sector, so far, is lacking.

This paper elucidates the economic efficiency of different *Acacia* hybrid timber plantation models with rotation ranging from 5 years to 12 years 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. Cost benefit analysis (CBA) and Faustmann model were employed for data analysis. The findings were validated in group discussions and expert interviews.

The results demonstrated that Acacia hybrid production was financially profitable for timber producers with the 11 years rotation plantation model indicating the highest benefit cost ration of 3.96. In addition, there was an increase in net present value (NPV) as the length of the plantation rotation increased from 5 years (1124 USD ha⁻¹) to 11 years (2919 USD ha⁻¹). However, a reduction of NPV was recorded with the 12 years rotation plantation model at 2769 USD ha⁻¹. A same trend was observed with benefit-cost ratio (BCR) of 2.41, 3.96 and 3.89 at 5 years, 11 years and 12 years rotation plantation respectively, internal rate of return (IRR) of 46%, 33% and 30%, and annual equivalent value (AEV) of 312 USD ha⁻¹, 567 USD ha⁻¹ and 533 USD ha⁻¹. Recommendations referring to the improvement of timber production economic efficiency were delineated.

Keywords: CBA, central Vietnam, economic analysis, long rotation, small-scale producers

Contact Address: Tham La Thi, VNU University of Economics and Business, Vietnam National University, Economics for Social Issues, 144 xuan thuy street cau giay, Hanoi, Vietnam, e-mail: lathitham@vnu.edu.vn

Prospective analysis of land use dynamics in the town of N'Dali (North-East Benin)

N. Innocent Gbai, Rachidatou Zime Koto, Clément Adjire

Université d'Abomey-Calavi (UAC), Department of Geography and Regional Planning, Benin

The anthropisation of forest ecosystems has become a major environmental problem impacting biodiversity in the study area. The aim of this study is to assess the spatial and temporal dynamics of land-use units in the N'Dali town. The methodological approach was based on the use of satellite images, including Landsat TM from 1980, Landsat ETM from 2000 and Oli Tirs from 2020, with 30 m \times 30 m resolution. Processing was carried out using a method based on supervised classification. Analysis and interpretation focused on spatio-temporal dynamics, with the aim of determining the positive and negative effects in terms of vegetation cover increase and regression resulting from the various uses of wood resources. The result of all these efforts was the mapping of land-use units in the N'Dali town. The CA-MARKOV model under IDRISI Selva was used to model land use units for the 2060 horizon. The results show that the period from 1980 to 2000 saw a decline in natural formations (open forest and savannah, surface water) in favour of anthropogenic formations (settlements, grassland and thicket, plantations, field and fallow mosaics, field and fallow mosaics under plantations). Savannahs and gallery forests declined by 68.69% and 69.32% respectively. Cultivated areas and housing increased by 206.54 % and 82.08 % respectively. Between 2000 and 2020, forests and gallery forests declined by 45.76 % and 37.92 % respectively. Anthropogenic units (cultivated, farmed and residential areas) have increased by 108.27 % and 180.47 %, respectively. Modelling of land-use units by 2060 showed a decline in forest, savannah and gallery forest of 5.28 %, 13.92 % and 15.78 %, respectively. Housing and cultivated areas increased by 8.57 % and 79.58 %, respectively in the town of N'Dali.

Keywords: Cartography, land use, modelling, N'Dali town, prospective analysis

Contact Address: N. Innocent Gbai, Université d'Abomey-Calavi (UAC), Department of Geography and Regional Planning, 677, RAS Abomey-calavi, Benin, e-mail: gbainofodo@gmail.com

Spatio-temporal changes of soil microbial communities under different land cover types in eastern Madagascar

Vahatra Rakotonindrina¹, Andry Andriamananjara¹, Tantely Razafimbelo¹, Papa Saliou Sarr²

¹University of Antananarivo, Laboratoire des Radioisotopes, Madagascar

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

Soil microorganisms play an important role in nutrient cycling. Understanding how soil microbial communities change across different land cover types and seasons is crucial for identifying the impact of soil microorganisms on ecosystem functioning. This study investigated the spatial and temporal variability of soil microbial community composition associated with vegetation across various land cover types in eastern Madagascar. We collected soil samples from distinct land cover types (tree fallow, shrub fallow, eucalyptus forest, and degraded land) over three sampling seasons (dry season, beginning and end of rainy season). We then quantified total bacteria and fungi, along with gene markers for key functional groups involved in nutrient cycling (gcd, phoD, nifD), using molecular tools. Results showed a significant effect of land cover types on soil microbial community. Shrub fallow exhibited the highest relative abundance of microbial genes compared to degraded land. Shrub fallow also demonstrated greater vegetation species diversity after tree fallow, as indicated by the Shannon diversity index, highlighting the influence of vegetation on soil microbial diversity. Multiple linear regression and Pearson's correlation were applied to microbial parameters combined with soil physicochemical characteristics to investigate the impact of environmental factors on soil microbial composition. The analysis revealed that soil phosphorus (P) availability, after pH, was the primary factor regulating microbial relative abundance, especially for bacteria (p < 0.001). Our results, particularly in terms of predicted gene expression, revealed interesting patterns. Samples collected at the beginning of the rainy season generally exhibited the highest mean abundance except for gcd and nifD genes, which showed higher expression levels at the end of the rainy season. Despite the increased expression of the P-releasing gene in the rainy season, P availability was not correlated to microbial relative abundance. These findings contribute to our understanding of the complex interactions between soil microorganisms, land cover types, and environmental factors, and their impact on ecosystem functioning.

Keywords: Land cover, Madagascar, phosphorus, soil functioning, soil microorganisms

Contact Address: Vahatra Rakotonindrina, University of Antananarivo, Laboratoire des Radioisotopes, Lot ii E 8 bis ae ambohimirary route d'andraisoro, Antananarivo, Madagascar, e-mail: vahatra.rakotonindrina@gmail.com

Indications for forest restoration of the Turquino interpretive trail, Alto del Naranjo – La Platica sector, Cuba

Yandro Jimenez¹, Yudemir Cruz Pérez², Görres Grenzdörffer³

¹University of Granma, Forestry Engineering, Cuba ²University of Habana, Faculty of Tourism, Cuba ³University of Rostock, Geodesy and Geoinformatics, Germany

The research was carried out in the protected area "Parque Nacional Turquino", in the "Alto del Naranjo - La Platica" sector of the Turquino interpretive trail. In this area, the inadequate management of the ecosystem associated with the interpretive trail induces high levels of environmental deterioration in the montane rainforest. For the evaluation of the ecosystem and selection of actions, a floristic study of its structure and diversity was carried out, together with an evaluation of the state of conservation of the vegetation. The exploration was initially developed between the months of October 2014 and October 2015, the final data were taken between the months of October 2022 and September 2023. For data collection, a general inventory with systematic sampling was carried out, and 25 plots were collected. These plots were representative of species diversity, recording 3,123 individuals of 77 taxa belonging to 50 families. Spatial analyses were performed with QGIG software tools Version 3.34.0. The composition of the flora and the structure of the vegetation are due to secondary formations with ecotonal characteristics, superimposed by historical management practices lacking adequate regulation, which have served to deteriorate the forest. The state of conservation of the vegetation of the ecosystem associated with the trail is poor, based on the high degree of anthropogenic intervention, the unfavourable appearance of the vegetation, the low abundance of characteristic species, the disappearance of epiphytic sinusia and the discrete tenors of the leaf litter layer; with accentuated fragmentation and evident progressive deforestation. The indications for the forest restoration of the Turquino interpretive trail, Alto del Naranjo -La Platica sector, can be interpreted as an environmental alternative of ecological and socioeconomic management, which begins with the design of actions for sustainable development in the La Platica conservation zone based on forest intervention.

Keywords: Ecotourism, forest restoration, forestry, GIS, protected areas

Contact Address: Yandro Jimenez, University of Granma, Forestry Engineering, Zenea 327 entre Lora y Figueredo, 85100 Bayamo, Cuba, e-mail: yjimenezb83@gmail.com

Silver on the mountain: Value chain of *Morchella* spp. in Nepal

THI THUY DUONG NGUYEN¹, YALI WEN¹, THAM LA THI ² ¹Beijing Forestry University, School of Economics and Management, China ²VNU University of Economics and Business, Vietnam National University, Vietnam

Non-timber forest products (NTFPs) represent a natural resource that provides value from the local to the international economy through market and nonmarket recreational channels. In Nepal, with an annual trading value of around 25 million Nepalese Rupees, NTFPs are considered an essential alternative income source, especially for those residing in mountainous areas. Of these NTFPs, *Morchella* spp. (morels) is one of the most important and prioritised species due to its multiple purpose uses. Despite its environmental benefits and socioeconomic improvement potential, a comprehensive analysis of the configuration and characteristics of morels collection and trade system so far is lacking.

This paper elucidates the structure of Morels value chains (VCs) in 15 districts, one each in the physiographic zone of high mountains, middle hills and terrain, and in each development region of Far-Western, Mid-Western, Western, Central and Eastern Nepal. Eighty-six in-depth interviews were conducted with different actors in the chains. The findings were validated through direct observations and in 15 group discussions and 45 expert interviews.

The results demonstrated a network of economic stakeholders directing the flow of morels products to the end of the market. There were four actor groups including collectors, traders, central wholesalers and regional wholesalers which participated in the morels VCs to different extents. Additionally, various institutional actors, such as the District Forest Department and the Community Forest User Group provided support and facilities for the VC performance. Regarding governance modes, vertically, the buyers had the upper hand in almost all transactions along the chains. Furthermore, there was a considerable lack of horizontal coordination between stakeholders despite its importance in capturing the added value created. Recommendations referring to the improvement of morels VCs were delineated.

Keywords: Governance nodes, stakeholders, value chain configuration, value chain upgrading, wild edible fungi

Contact Address: Thi Thuy Duong Nguyen, Beijing Forestry University, School of Economics and Management, 35 qinghua east road haidian district, 100083 Beijing, China, e-mail: thuyduongnguyen.218@outlook.com

Filling gaps in landscape fires detection, emission and management in Africa

Boris Ouattara¹, Kwame Hackman²

¹*Thünen Institute for Climate-Smart Agriculture, Germany* ²*West African Science Service Center on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso*

Biomass burning plays a pivotal role in shaping ecosystems and influencing atmospheric dynamics. Access to accurate and current information on burned areas (BA) is essential for comprehending the root causes of fires and their subsequent impacts. Various countries have been experimenting with BA mapping products within diverse fire monitoring systems. However, a holistic approach to wildfire prevention has been hindered by the absence of standardised information on fires, particularly in West Africa. This study introduces two products from our fire information system tool aimed at addressing the gap in fire and emission measurement, monitoring, statistical analysis, and reporting. This system represents a comprehensive fire management solution leveraging Earth observation data, notably the Visible Infrared Imaging Radiometer Suite (VIIRS) remote sensing technology. The first product, VIIRS-BA, is a BA dataset generated at a 250 m resolution using the Google Earth Engine cloud computing environment. The second, VIIRS-EM, estimates fire-induced greenhouse gases and aerosols for 40 species employing the fire radiative power approach. Our emission inventory offers a spatial resolution that can be adjusted to a minimum of 375 m. Enhancements in input data, particularly through increased spatial resolution, hold promise for significantly improving the accuracy of fire activity detection and monitoring efforts, particularly for small fires often overlooked by current emission inventories. These delivered products, serving as climate and ecosystem services, align with the objective of empowering decision-making and policy development regarding fire monitoring, emissions, and mitigation strategies in the African region. These tools will be overseen by the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) competence center. Case studies will be utilised to demonstrate their practical applications, potentially positioning WASCAL as a primary provider of wildfire and smoke-related services in Africa. For end-users, the outputs will be integrated into local to regional-level geographic information system formats. The findings derived from this research could prove invaluable in the planning and monitoring of prescribed burns, and they may also serve as a baseline for future fire mitigation projects.

Keywords: Biomass burning, climate, ecosystem services, earth observation, fire management, emissions, sub-Saharan Africa

Contact Address: Boris Ouattara, Thünen Institute for Climate-Smart Agriculture, Braunschweig, Germany, e-mail: boris.ouattara@thuenen.de

Challenges and strategies for post-mine land restoration efforts in Ghana

Joshua Aggrey¹, Albert Kobina Mensah², Tim K. Loos³

¹Nat4life Ghana Ltd, Ghana

²Council for Scientific and Industrial Research-Soil Research Inst. (CSIR), Soil Science, Ghana

³GIZ GMBH, Germany

Gold mining in Ghana poses serious environmental and socio-economic challenges creating a soulless habitat for human and animal species, despite the existence of legal and regulatory frameworks, to address environmentalrelated hazards due to mining.

Nevertheless, there is a scarcity of information regarding the practical implementation of this and adherence to regulatory instruments. This study utilised policy analysis, participatory net mapping, expert interviews, and focus group discussions to delve into the experiences of after-mining land reclamation strategies from four communities in the Ashanti region of Ghana. Complementarily, a survey of 100 households was also conducted. The study identified revegetation, soil management, landfilling, community participation, and integrated water management as the primary methods of reclamation. Even though these practices constitute fundamental agricultural activities within the selected communities, the findings reveal that there are instances of failed or unsuccessful reclamation. The lower rate of reclamation efforts in the studied communities was attributed to weak policies and regulations, insufficient enforcement due to limited human resources capability, logistical and budgetary restrictions, lack of education and training, and key stakeholders that have been neglected in the mining and reclamation value chain.

We recommend that authorities augment their efforts in capacity-building programmes for both miners and the residents. Moreover, there must be effective coordination among all stakeholders, particularly regulators, traditional authorities, mining firms, and NGOs involved in the mining value chain. This could be achieved by enhancing the quality of communication, promoting transparency, and embracing divergent viewpoints from all stakeholders who matter in achieving a successful mine-land reclamation.

Keywords: Environmental challenges, land reclamation, mining policies, participatory net-maps, post-mine land use

Contact Address: Joshua Aggrey, Nat4life Ghana Ltd, Sebrepor villa michel camp, 0000 Tema, Ghana, e-mail: joshua.aggrey@nat4life.org

Bases for the sustainable use of non-timber forest products in the La Platica community, Cuba

YANDRO JIMENEZ¹, BETTINA EICHLER-LÖBERMANN², RAUL LOPEZ³ ¹University of Granma, Forestry Engineering, Cuba ²University of Rostock, Agricultural and Environmental Faculty, Germany ³University of Granma, Plant Biotechnology Study Center, Cuba

Bases for the sustainable use of non-timber forest products and disused plants in the Ecological Community La Platica, is the result of a research carried out in 2023 with periodic field reports since 2018 in the Turquino National Park, and completed in the framework of the DAAD UnderPlanet project, consortium of five universities led by the University of Rostock, in Germany. With the aim of diagnosing non-timber forest products and identifying principles for the management of non-timber forest products and disused plants. Completion of the report required a biometric study of non-timber forest species, an ethnobotanical study focusing on species with medicinal, food and aromatic uses, and an expert evaluation to determine management principles. The main findings include the following The way in which non-timber forest products are harvested and marketed in the La Platica Ecological Community is due to unsustainable historical practices, characterised by low participation of local people in financial benefits and decision-making, failure to resolve tensions caused by inhomogeneous development and a production system that does not respect the obligation to preserve the environmental basis for development. The possibility of carrying out new production, transformation and marketing, based on the rescue of the physical infrastructure and the training of human capital. The management principles were: use and management of natural resources, financial capacity, physical infrastructure, human capacity and socio-cultural and organisational aspects. Finally, the principles of management and the basis for the use of non-timber forest products in the Ecological Community of La Platica can be interpreted as a sustainable proposal, in which the natural capital must be used according to its potential and carrying capacity, and the economic and social capital must be adapted to the characteristics of the natural capital.

Keywords: Disused plants, environmental management, non-timber forest products

Contact Address: Yandro Jimenez, University of Granma, Forestry Engineering, Zenea 327 entre Lora y Figueredo, 85100 Bayamo, Cuba, e-mail: yjimenezb83@gmail.com

Aboveground biomass models for trees and shrubs of exclosures in the drylands of Tigray, northern Ethiopia

 $\begin{array}{c} Mengesteab \ Hailu \ Ubuy^1, \ Tron \ Eid^2, \ Ole \ Martin \ Bollandsas^2, \\ Emiru \ Birhane^1 \end{array}$

¹Mekelle University, Land Resource Management and Environmental Protection, Ethiopia ²Norwegian 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- R², and root mean square errors and mean prediction errors (MPEs) from a leave-one-out-cross-validation procedure. Pseudo- R² 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 "pantropical" 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, Land Resource Management and Environmental Protection, P.O Box 231 Arid Campus, Mekelle, Ethiopia, e-mail: mengesteabh@gmail.com

Trees outside forests: agroforestry and urban trees

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Effects of canopy management of of umbrella tree (*Terminalia brownii* Fres.) on microclimate and maize (*Zea mays* L.) yield in agroforestry parkland of South Ari District, Southern Ethiopia

Mitiku Ayele Handiso 1,3 , Zebene Asfaw², Bruno Glaser³, Tobias Bromm³, Arthur Gross³, Bruk Lemma 4,3

¹Jinka Agricultural Research Center, Southern Agricultural Research Institute, Agroforestry, Ethiopia

²Hawassa University, Wondo Genet College of Forestry and Natural Resources, Ethiopia ³Martin Luther University Halle-Wittenberg, Inst. of Agricultural and Nutritional Sci., Soil Biogeochemistry, Germany

⁴Ethiopian Biodiversity Institute, Forest and Rangeland Biodiversity Direct., Ethiopia

Smallholder farmers manage trees on crop fields in the South Ari District of southern Ethiopia through pruning and pollarding. Among those trees, Terminalia brownii is one of the preferred and dominant tree species, with numerous multipurpose uses such as tools, firewood, charcoal, medicine, shade, and soil improvement. However, the effects of their canopy management on microclimate and maize yield have not been scientifically quantified; even the results of other tree studies have been contradictory. Hence, this study investigated how Terminalia brownii canopy management affects microclimate and maize yield in parkland agroforestry. As part of the study, data were collected on microclimate and maize yield at three different distances from the tree trunks to the open field: D1 (0-4.1 m), D2 (4.1-8.2 m), and D3 (15 m outside)the tree canopy cover). The study also included three different tree canopy management treatments (pollarding, pruning, and control), which were replicated three times in a randomised complete block design with a factorial arrangement. The study results revealed that canopy management of the tree influenced the microclimate, which in turn influenced yield. Statistically significant differences (p < 0.05) were observed in the yield and yield components of maize when grown under tree canopies compared to open fields under either canopy-managed trees or control. The highest grain yields (3,717 kg ha⁻¹ and 3,718 kg ha⁻¹, respectively) were observed in plots with pruned and pollarded trees, while the lowest yield $(2,642 \text{ kg ha}^{-1})$ was obtained from the control plot. The observed differences in yield might be due to the highly concentrated soil nutrients, modified microclimate under the tree canopies, and reduced shading effects under canopy-managed trees. It is therefore recommended that either pruning or pollarding of Terminalia brownii trees be adopted to enhance yield by modifying the microclimate and improving soil nutrients.

Keywords: Agroforestry, maize productivity, microclimate, open field, shading effects, tree management

Contact Address: Mitiku Ayele Handiso, Jinka Agricultural Research Center, Southern Agricultural Research Institute, Agroforestry, 4420 Jinka, Ethiopia, e-mail: mitikuayele43@gmail.com

Unveiling urbanisation effects on trees outside forests dynamics along the urban-rural gradient in Bengaluru, India

TAO JIANG, CHRISTOPH KLEINN, MAXIMILIAN FREUDENBERG, NILS NÖLKE University of Goettingen, Forest Inventory and Remote Sensing, Germany

Rapid urbanisation transforms urban-rural gradients, particularly in larger cities, shaping diverse landscapes through human activities. This dynamic affects the distribution and characteristics of urban trees, a subset of "Trees Outside Forests" (TOF), crucial for informed decision-making in urban planning, conservation, and sustainable land management. High-resolution satellite imagery is essential for comprehensive TOF monitoring, but accurately identifying individual trees remains challenging due to crown heterogeneity and spectral similarities with other vegetation. Deep learning, such as detection transformer models (DETR), offers new avenues for efficient and accurate TOF image analysis. In this study, we propose an end-to-end object detection approach for large-area tree detection based on a DETR architecture called DINO. we employed this tree detection approach and identified 1.3 million trees in a study area that covers the urban-rural gradient of Bengaluru, a megacity in India. Additionally, we developed an allometric equation to estimate DBH from the tree crown diameter as derived from the detected bounding boxes. Our study focused on analysing variations in tree density and tree size along this gradient. Comparative analyses highlight DINO's superior detection performance with a SWIN transformer backbone, achieving an F1 score of 74% and an AP of 76%, surpassing other models like Faster RCNN, YOLO, and other DETR variants. Further validation in Delhi and Shanghai demonstrated consistent performance of proposed tree detection approach, yielding F1 scores of 87% and 73%, respectively. The findings revealed distinct patterns: urban domains displayed larger tree crown diameters (mean CD: 8.87 m) and diameters at breast height (mean DBH: 43.78 cm) despite having the lowest tree density (32 tree per hectare). Furthermore, as distance from city centre increased, tree density showed an upwards trend, while the mean tree crown diameter and mean tree basal area decreased: there are clear differences of urban tree density and size between urban and rural domains in Bengaluru. This study offers a methodology that helps generating instructive insights into the dynamics of urban trees along the urban-rural gradient. This may inform urban planning and management strategies for enhancing green infrastructure and biodiversity conservation in rapidly urbanizing cities like Bengaluru.

Keywords: Deep learning, high resolution satellite imagery, trees outside forests, urbanisation

Contact Address: Tao Jiang, University of Goettingen, Forest Inventory and Remote Sensing, Büsgenweg 5, 37075 Göttingen, Germany, e-mail: tjiang@gwdg.de
The green credit plan: An initiative of the Indian government contributing towards natural climate solution

Vindhya Prasad Tewari

International Society of Tropical Foresters, India Chapter, India

If the environment is gainer when more trees are planted, there is an incentives for individuals and various entities also also for greening barren patches in India. The Green Credit Program launched by the Indian government in October 2023 provides tradable credits for afforestation efforts. One green credit will be awarded per tree planted on identified land parcels subject to a minimum density of 1100 trees per ha based on local climatic and soil conditions. These credits will be made available for trading on a domestic market platform. Out of total 328.7 Mha of India's total geographical area, 96.4 Mha land (29.3%) is affected by desertification/degradation and 26 Mha of degraded land is expected to be restored by the Indian government by 2030. The forest department will identify degraded land parcels under their control and make available them for plantation. So far, over 10, 000 hectares of such lands have been identified for tree plantation across 13 states under the green credit program. After tree planting is completed, forest department will submit repot to the Administrator who will evaluate and verify the work done and award green credits to applicant based on the total number of trees planted on the assigned land parcel that can be traded on a designated trading platform to be maintained by the administrator. This initiative is an innovative idea of the government to tackle the climate change vagaries and provides a nature based climatic solution to the country who is facing the wrath of climate change.

Keywords: Climate change, degraded lands, green credit, natural climate solution, tree planting

Contact Address: Vindhya Prasad Tewari, International Society of Tropical Foresters, India Chapter, 4/909, Sector-4, Gomti Nagar Extension, 226010 Lucknow, India, e-mail: tewarivp@gmail.com

Sustainable cocoa agroforestry in Côte d'Ivoire: Enhancing organic fertilisation for upgraded nature's contributions to people

HANNAH-CELINE CAMINADA¹, GOETZ UCKERT², STEFAN SIEBER² ¹Ghent University, Faculty of Bioscience Engineering, Germany ²Leibniz Centre for Agric. Landscape Research (ZALF), Germany

The EU's recent ambitions to conserve natural rain forests by banning imports from deforested areas urges local production systems to adapt. In Côte d'Ivoire, increased organic fertilisation has been identified as suitable solution for adjusting traditionally transient cocoa farming systems. Not only can organic fertilisation circumvent ongoing deforestation, but possible simultaneous positive effects on soil and plant health, yields and community well-being are registered. Nonetheless, its application in Côte d'Ivoire's cocoa production remains scarce and must be enhanced. This study aimed at (1) identifying behaviour-underlying reasons for the low levels of organic fertilisation in Côte d'Ivoire's cocoa production, and (2) finding ways to boost its application while maximising related Nature's Contributions to People. Q-methodology was applied to identify prevalent attitudes shaping fertilisation behaviour in cocoa farming in southeast Côte d'Ivoire among a diverse group of 39 stakeholders. Participants' comparative ranking of 40 statements about fertilisation from "most agreed" to "least agreed" and subsequent commenting helped to display their personal perceptions. Factor analysis and qualitative evaluation of all perceptions revealed three common viewpoints explaining 43% of the study variance. "Informed status-quo defenders" overly strive for profitability and consider low availability of commercial organic fertilisers a major constraint. "Green-minded optimists" see issues in insufficient cooperation and organisation and place sustainability as their highest farming priority. The group of "open-minded autonomists" identifies a major obstacle in limited knowledge and accompaniment of farmers. Highly valuing their independence this group follows a path of subsistence agroforestry. Evaluating these perceptions' compatibility with existing fertiliser options' properties helped to identify ways to enhance organic fertilisation and related Nature's contributions to People. A) Adapting training and knowledge dissemination, b) increasing cooperation, and c) tailoring economic incentives are recommended as suitable areas of action. Aligning fertilisers' properties with stakeholders' needs, they can induce higher application rates and realise elevated Nature's Contributions to People while obeying the EU's deforestation ban. Applying similar approaches in different conservation contexts may be likewise useful to make sustainable practices more appealing to target audiences. This can assure more rapid and effective compliance with the future's proposedly increasing needs for conservation and sustainability efforts.

Keywords: Cocoa agroforestry, individual behaviour, nature's contributions to people, organic fertiliser, policy recommendations, Q-methodology, sustainability

Contact Address: Hannah-Celine Caminada, Ghent University, Faculty of Bioscience Engineering, Im Füllenschlag 3, 65510 Idstein, Germany, e-mail: hannahcaminada@arcor.de

Effect of soil compaction by livestock on tree roots in a silvopastoral system

Basiru Bojang, Ansumana Jarju

National Agriculture Research Institute (NARI), Cropping System and Agroforestry Research Directorate, Gambia

This thesis provides an understanding of ecophysiological effect of livestock integration in agroforestry systems. Integration of livestock with trees and pastures referred to as "silvopastoral" has been identified as a suitable candidate for sustainable ecosystem balanced natural resources management. In order to identify the long term impact of livestock integration in silvopastoral system, a research was conducted in an established university of Wales, Bangor silvopastoral network research site at Henfaes, to determine the effect of soil compaction by livestock on tree roots.

Two multipurpose tree genotype (sycamore and alder) were measured to determine the extent of soil compaction and root development at three distance (0.5 m, 1.0 m and 2.5 m) in north and west directions from sample trees. Sampling was carried out from a single randomly selected tree per plot in sycamore 100, sycamore 400, alder 400, sycamore (clump 400) densities in 3 replications. In sycamore 2500 and alder 2500 forestry control treatments, measurements were made only at two distance and direction, measurements of soil compaction (use of penetrometer) and root development (use of soil corer) was carried out to depth of 30 cm horizons, sub sampled to (0-10, 10-20 and 20–30 cm respectively). Results on root development indicated a significant interaction between tree density and distance from tree in terms of root length, number of root tips, and forks. Lowest density (sycamore 100) recorded the lowest mean value of root length (11.51vm), number of roots tips (12), and number of root folks (9) at 2.5 m distance across replications. When compared with sycamore 400 root length (15.25 cm), tips (17), and forks (13); alder 400 root length (16.27 cm), tips (21), and forks (14); Sycamore clump 400 root length (16.64 cm), tips (18), and forks (15), there was statistically significant difference. With the inclusion of forestry control (2500 densities), distance from tree up to 1.0 meters did not make any difference in root parameters among treatments. On the other hand, penetrometer pressure test for soil compaction has shown higher-pressure requirement up to (152.67LB north and 161.0 LB west) at 2.5 meters distance in the sycamore 100 density.

Keywords: Agroforestry, ecophysiological effect, silvopastoral system

Contact Address: Basiru Bojang, National Agriculture Research Institute (NARI), Cropping System and Agroforestry Research Directorate, Brikama, 00220 Banjul, Gambia, e-mail: basirubojang11@gmail.com

Enhancing landscape connectivity through agroforests: The case of Gedeo's agroforests in Ethiopia

HAFTE TESFAY¹, MESELE NEGASH²

¹BOKU University, Forest and Soil Science, Austria

²*Hawassa University, Wondo Genet College of Forestry and Natural Resources, Agroforestry, Ethiopia*

The Gedeo agroforestry cultural landscape in Ethiopia is recognised as a leading example of sustainable agroforestry practices. It mimics and resembles natural forest, characterised by vertically and horizontally diverse composition, structure, and functionality that contribute to on-farm conservation, environmental well-being, and livelihood support systems. Numerous studies have highlighted the positive impacts of agroforests in the landscape on *circa* situm biodiversity conservation, implying biodiversity conservation through utilisation. Agroforests provide additional habitats for species that are sensitive to disturbance, conserve the gene pools of native tree species, and enhance biodiversity. They also act as buffers against forest degradation and deforestation in the surrounding natural habitats as well as connecting fragmented habitats for animal and plant species through the creation of corridors and stepping stones. Agroforests in the Gedeo landscape serve as important havens for preserving high levels of diversity. The smallholder agroforests in the region play a crucial role in conserving tropical woody plant species as circa situm reservoirs of biodiversity in agricultural environments. Previous studies have shown that the diverse species composition within agroforests contributes significantly to biomass and carbon storage, which in turn helps to mitigate climate change. For the Gedeo people, agroforestry is not just a supplementary livelihood activity but rather a mainstay. In summary, the Gedeo agroforests play a significant role in enhancing landscape connectivity and contribute to the integrity and sustainability of the agricultural production system. However, the Gedeo agroforests also face challenges including land degradation and fragmentation, the emergence of lucrative monoculture cash crops, climate change, limited market access, lack of financial resources, and insufficient technical knowledge and training.

Keywords: Agroforest, *circa situm* conservation, Gedeo landscape, landscape connectivity

Contact Address: Hafte Tesfay, BOKU University, Forest and Soil Science, Peter-Jordanstrasse 82, 1190 Vienna, Austria, e-mail: hafte.tesfay@boku.ac.at

Leveraging state of the art computer vision models for tree monitoring in silvopastoral systems

ANDRÉS FELIPE RUIZ, JUAN ANDRÉS CARDOSO The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

Silvopastoral systems allow the integration of trees with pastures offering a sustainable approach for livestock production. The effective monitoring of trees in this kind of system is essential for improved management in terms of productivity, follow-up, biomass estimation, livestock well-being, and environmental impact assessment. This study explores the application of recent advancements in artificial intelligence models for this purpose, particularly computer vision models applied to remote sensing imagery. Given the characteristic of the available data in the form of satellite and aerial RGB images, some models were tested for different computer vision tasks like tree detection, tree semantic segmentation and tree instance segmentation. These preliminary tasks can be used for subsequent analyses like tree counting, biomass estimation, and monitoring tree development. The general approach was to leverage pre-existing models, but depending on the model characteristics and data availability, different approaches were analysed. Some of the tested models were specifically designed for tree analysis (DeepForest, DetectTree, TreeCrownDelineation, TreeFormer), others conformed a wellestablished computer vision architecture (U-Net, Mask R-CNN), and some of the most recent models were tested to assess their capabilities as foundation models (Segment Anything Model). According to the model's capabilities, the methodology involved applying either model full training, transfer learning, out-of-the-box inference, or fine-tuning. Pre-trained models like U-Net are useful for semantic segmentation, while others like Mask R-CNN perform better for instance segmentation, and DeepForest for object detection. The most recent vision transformers were also compared. This work identifies the most promising models in terms of usability, acknowledging their advantages and limitations, and a user-friendly tool was developed to facilitate the application of these models in practice.

Keywords: Artificial intelligence, computer vision, deep learning, remote sensing, silvopastoral systems

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

Characterisation of managed ecosystems in buffers zones of the Dja biosphere reserve: Implication for tree domestication and biodiversity conservation

Armel Gael Mouaffo 1 , Christian Nguenga Nongni 2 , Irene Franceline Mbouwe 1

¹*Higher Institute of Environmental Sciences, Agroforestry, Cameroon* ²*University of Dschang, Natural Ressource Management, Cameroon*

Improving and maintaining landscapes that provide ecosystem services has been identified as a critical goal for sustainable natural resource management and conservation. This study was conducted with the aim of identifying priority plants species whose domestication would contribute most to the sustainable management of wood resources and to the improvement of the well-being of local communities'. Plots have been realised for the inventory of the forests and the agroforests and also for the description of trees, shrubs and regeneration. Socio-economic and ethnobotanical surveys provided information on agroforestry systems established, the level of integration of agroforestry and the different plants used. Results indicate that 100 % of agroforestry households use a complex agroforestry system based on cocoa and banana. 70% of respondents believe that the practice of agroforestry has a positive impact on production yields. Populations harvest the majority of non-timber forest products (NTFPs) for food and medicinal purposes in forests with 53% of harvests made exclusively in forest, 41% in both forests and agroforests, and only 6% in agroforests. 82% of respondents believe that domestication of NTFPs and their integration into agroforestry plots would be essential for their wellbeing. Plants are mainly used for food (46%) and medicinal (30%) purposes. Baillonella toxisperma is the most used plant in the village. The most common species in the forest is Petersianthus macrocarpus, followed by Heisteria pavifolia, Plagiostyles africana. Forests have a diametrical structure in the form of a decreasing exponential function characteristic of tropical dense forests. The shanon index shows us that the diversity of Somalomo forests is close to that of agroforests. The priority index (PI) for domestication taking into account ethnobotanical and ecological data was calculated. Priority woody species, whose domestication would contribute to the conservation of biodiversity in the study area are: Alstonia boonei (PI=72), Dichapetalum sp (PI=68), Strombosia pustulata (PI=68), and Baillonella toxisperma (PI=67).

Keywords: Biosphere reserve, ethnobotany, non timber forest products

Contact Address: Armel Gael Mouaffo, Higher Institute of Environmental Sciences, Agroforestry, 7292, 0000 Yaoundé, Cameroon, e-mail: armelgaelmouaffo@yahoo.fr

Target-oriented spectral index distribution parameters for estimating leaf chlorophyll content from three-dimensional RGB point clouds in an olive orchard in Tunisia

 $\begin{array}{l} Marius \ Hobart^1, Olfa \ Boussadia^2, \ Pierre \ Ellssel^3, \ Amel \ Ben \ Hamouda^2, \\ Magdalena \ Schwarze^1, \ Michael \ Schirrmann^1 \end{array}$

¹Leibniz Inst. for Agricultural Engineering and Bioeconomy (ATB), Agromechatronics, Germany

²Olive Institute (IO), Tunisia

³BOKU University, Dept. of Crop Sciences, Austria

An important parameter in the site-specific management of an olive orchard is the leaf chlorophyll and nitrogen content. However, the ground-based measurement of these parameters is laborious and time-consuming. Therefore, the field study shown here attempts to model the target parameter from spectral indices based on low-budget RGB imagery collected from drones.

Field experiments took place in July 2022 on an olive orchard in Toukaber (36°42°22 N, 9°30′38 Ë, governorate of Beja, Tunisia) with a size of 0.73 ha and covered 72 trees. A Mavic 2 Enterprise Dual (DJI, China) with a 1/2.3K-MOS 12MP sensor chip was used for the drone flight campaign at an altitude of 30 m. The ground sampling distance was about 2.5 mm and the images were taken with an 80 % overlap. On the same day, reference measurements of leaf chlorophyll and nitrogen were taken on 16 trees using the SPAD502+ chlorophyll metre (Spectrum Technologies Inc., USA). This indirect SPAD parameter was subsequently defined as the target parameter for the model estimation. A point cloud was derived photogrammetrically from the RGB image data set and tree-specific spectral indices, the normalised green red difference index (NGRDI) and the green leaf index (GLI), were created for each crown point. Statistical distribution parameters are used to model the mean SPAD value per tree crown.

It can be shown that a general derivation of the SPAD value from drone-based low-budget RGB image data is possible. The optimal model fit uses 6 parameters (NGRDImax, NGRDI1.quantile, GLI1.quantile, GLI1.quantile, GLI3.quantile) and achieves a corrected r^2 of about 0.57. With the derived model, the SPAD value can be estimated for each tree at the test site. It remains to be researched whether the model is stable across locations and seasons.

Keywords: Gli, olive, spectral index, Tunisia

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

Analysing the charcoal value chain in the changing landscape of Turkana, north west Kenya

REAGAN OTIENO OCHIENG, CAROLINE HAMBLOCH, DAGMAR MITHÖFER Humboldt-Universität zu Berlin, Albrecht Daniel Thaer-Inst. of Agricultural and Horticultural Sciences, Germany

The charcoal value chain in Kenya is a vital aspect of rural livelihoods and environmental sustainability. However, it operates illegally within a dynamic landscape. This thesis provides a comprehensive analysis of the charcoal value chain in the evolving landscapes of Turkana, located in the northwestern part of Kenya. The objective of this study is to examine the effects of the charcoal value chain on sustainable rural livelihoods. It aims to identify threats to sustainability by pinpointing sustainability hotspots in terms of social, economic, and environmental dimensions for targeted interventions. This research employs a mixed-method approach that integrates value chain analysis, sustainable rural livelihood assessment, and sustainability hotspot analysis. The aim is to investigate the complex interactions between charcoal production, distribution, marketing, and end-use within the context of evolving socio-economic and environmental aspects. This study examines the preconditions for transforming the charcoal value chain into a more sustainable and just one in Turkana. It considers the roles of charcoal and the different livelihood strategies of pastoralists and agro-pastoralists in Loima Sub-County in Turkana. The study uses key informant interviews, focus group discussions, surveys, stakeholder meetings, participatory workshops, photovoice, and field observation techniques The key finding reveals that the charcoal ban has not enabled households to shift to clean energy. Instead, it has increased the number of households falling back to cheap, unclean sources of energy such as firewood. This has led to more tree-cutting as the prices for charcoal and other sources of fuel have surged up in Turkana. The analysis of sustainability hotspots has identified the wood harvesting and charcoal processing stages as areas of heightened vulnerability and unsustainability within the charcoal value chain. The thesis provides insights into the spatial distribution of challenges and opportunities for interventions to enhance the sustainability of the charcoal value chain in Turkana. By addressing the governance gap, promoting alternative livelihood strategies, and fostering stakeholder collaboration, while balancing economic viability with environmental stewardship and social equity in Turkana.

Keywords: Charcoal value chains, livelihood strategies, Loima sub-county, participatory approach, photovoice, Turkana

Contact Address: Reagan Otieno Ochieng, Humboldt-Universität zu Berlin, Albrecht Daniel Thaer-Inst. of Agricultural and Horticultural Sciences, Berlin, Germany, e-mail: ochiengr@hu-berlin.de

Impact of shade tree species and soil type on root traits in cocoa agroforestry system

Klara Kegler, Munir Hoffmann, Reimund P. Rötter, Issaka Abdulai

University of Goettingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany

Climate change is threatening agricultural systems worldwide, with tropical countries being most vulnerable to the impacts of altering precipitation and temperature patterns. In Ghana and other West African countries with over 70% of global cocoa production, agroforestry has the potential to enhance climate resilience and crop yield stability. However, it remains difficult to determine decisive shade tree traits that affect productivity and climate resilience. In such a complex system, it is crucial to consider not only aboveground indicators but include information from belowground. Roots can provide valuable insights about a plant's condition and its response strategies to environmental changes. This study aims to determine the extent to which shade trees and soil type influence root traits over both temporal and spatial scale. We determined whether root traits vary under a shade tree compared to those growing beyond the shade tree's impact zone. On a smallholder cocoa farm in south-east Brong-Ahafo region, Ghana, two common shade tree species with contrasting leaf phenology were observed. Terminalia superba sheds and emerges leaves during the dry season while ivorensis sheds leaves only at the end of the dry season. This difference in timing could lead to different competition patterns and hence variable root development under those trees when water is limiting. To access root characteristics over the drought period, the CI-600 root imager was used to take scans in October 2023, December 2023 and February 2024 within the shade tree sub canopy and in full sun control plots. After analysing the images with the RootSnap software, root parameters such as average diameter and root length density will be related to hydrological soil conditions in loamy and sandy soils. Further, the question of whether in situ root scanning is a suitable technique for this specific research setting will be answered. By comparing the CI-600 in situ images to manually sampled roots, the accuracy of this time-saving method shall be quantified. Final results will provide for both a more detailed knowledge about influential shade tree parameters in a tropical agroforestry system and a first evaluation of suitability of in situ root imaging techniques in agroforestry systems research.

Keywords: Cocoa, leaf phenology, physiological traits, root parameters

Contact Address: Klara Kegler, University of Goettingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Grisebachstraße 6, Goettingen, Germany, e-mail: k.kegler@stud.uni-goettingen.de

Relationship between habitat characteristics and acoustic ecological indicators in cocoa agroforestry systems of Ghana

Amanda Cooke¹, Marlene Wätzold², Meike Wollni², Issaka Abdulai³, Carolina Ocampo-Ariza⁴

 $^1 University \ of \ G\"{o}ttingen, \ Dept. \ of \ Forest \ Inventory \ and \ Remote \ Sensing, \ Germany$

²University of Göttingen, Dept. of Agric. Econ. and Rural Dev., Germany

³University of Goettingen, Dept. of Crop Sciences: Tropical Plant Production and Agricultural Systems Modelling (TROPAGS), Germany

⁴University of Göttingen, Dept. of Functional Agrobiodiversity, Germany

West African cocoa makes up 70% of the world market, including 25% grown by Ghanaian small-holder farmers. Nearly 2 million farmers grow cocoa (Theobroma ca*cao*) in West Africa and a high percentage live in poverty. Increased cocoa production has resulted in major forest loss and species population declines in Ghana. Therefore, the sustainable production of cocoa is critical to provide the greatest benefit through economic viability while maintaining biodiversity and ecosystem services. Growing cocoa with shade trees in agroforestry systems has been proposed as a suitable way to maintain habitat on cocoa farms while providing other benefits such as food and timber. The relationships between cocoa yield, water usage, nutrient balances, and shade trees have been widely established in the literature. However, there is a significant knowledge gap in understanding the relationships between cocoa agroforestry habitat characteristics and biodiversity. Birds and bats are commonly used ecological indicators because of their sensitivity to changes in their environment and correlation to biodiversity in other taxonomic groups. This study uses bioacoustic monitoring and indices for the first time to study actors influencing biodiversity on West African cocoa farms. We carried out cocoa farm tree inventories and 24-hour bioacoustic sound recordings from November 2022 – February 2023 on 119 cocoa farms in four regions across the moist semi-deciduous forest zone of Ghana. We estimated landscape-level tree cover using the NDVI from satellite imagery. A general linear mixed-effects model was used to determine the effects of on-farm habitat characteristics and landscapelevel tree cover on the Bioacoustic Index (BI) and Acoustic Complexity Index (ACI); bird richness, abundance, and species composition; and bat occupancy. We hypothesise that the BI and ACI will be positively associated with farm-level herbaceous cover, crown area, and landscape-level tree cover. In addition, we hypothesise that bird richness and bat occupancy will be more positively associated with landscape-level tree cover than farm-level habitat characteristics due to their larger ranges. The results of this study will provide valuable insights into how cocoa farm habitat and landscapelevel tree cover affect biodiversity on cocoa farms, including implications for farm- and landscape-level conservation policy and cocoa production.

Keywords: Bat occupancy, bioacoustics, bird species richness, cocoa agroforestry

Contact Address: Amanda Cooke, University of Göttingen, Dept. of Forest Inventory and Remote Sensing, Büsgenweg 5, 37077 Göttingen, Germany, e-mail: amanda.cooke@stud.uni-goettingen.de

Deforestation in forest-savannah transition zone of Ghana: Boabeng-Fiema monkey sanctuary

Afua Amponsah Amankwah¹, Jonathan-Arthur Quaye-Ballard², Bennetta Koomson¹, Richard Kwasi Amankwah³, Alfred Awotwi⁴, Bright O. Kankam⁵, Nana Yeboaa Opuni-Frimpong⁶, Douglas Siaw Baah¹, Stephen Adu-Bredu⁵

- ¹Kwame Nkrumah University of Sciences and Technology (KNUST), Dept. of Materials Engineering, Ghana
- ²*Kwame Nkrumah University of Sciences and Technology (KNUST), Dept. of Geometric Engineering, Ghana*
- ³University of Mines and Technology (UMaT), Dept. of Minerals Engineering, Ghana ⁴Ck Tedam University of Technology and Applied Sciences, Dept. of Environmental Science, Ghana
- ⁵Council for Scientific and Industrial Research, Forestry Research Institute of Ghana, Ghana

⁶University of Energy and Natural Resources, Forest Science, Ghana

Forests provide many resources, ecosystem services and absorb carbon dioxide, which helps in climate regulation. In spite of the enormous benefits of forests, the issue of deforestation is still ongoing. There has been a continuous decline in forests globally and the forest area of Boabeng Fiema Monkey Sanctuary (BFMS) in Ghana is facing a similar threat. The aim of the study is to determine the different forest cover types and changes in the forest of BFMS. Satellite images for the years 1992, 1998, 2004, 2010, 2016 and 2018 were downloaded. Unsupervised and supervised classification were performed to determine the different forest cover types and remote sensing software was used to detect the changes in the forest cover. The forest cover was classified into six classes; closed forest, open forest, savannah woodland, savannah, farmlands and built-up area. Available data suggests that between 1992 and 2018, closed forest decreased by 242.19 ha, open forest increased by 122.85 ha, savannah woodland increased by 7.47 ha, savannah increased by 6.48 ha, farmland increased by 39.39 ha and builtup area increased by 65.7 ha. The changes in closed forest, open forest, farmland and built-up were all significant. Decreasing forest cover of BFMS is a threat to sustainable ecotourism since the forest serves as a habitat and food source to the monkeys. This research serves as guide to other researches aiming at determining forest cover changes in forest-savannah transition zones. In addition, the results have produced an inventory of the forest, which will help forest resource managers sustainably manage the forest.

Keywords: Carbon, climate change, deforestation, ecotourism, forest-transition zone

Contact Address: Afua Amponsah Amankwah, Kwame Nkrumah University of Sciences and Technology (KNUST), Dept. of Materials Engineering

current address: University of Felix Houphouet-Boigny, Abidjan, Côte d'Ivoire, e-mail: maameafuaamponsah@gmail.com

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Gendered governance for sustainable transformations in agri-food systems

Ranjitha Puskur, Aayushi Malhotra, Kritika Goel

International Rice Research Institute, Evidence Module, CGIAR Gender Impact Platform, India

Agri-food systems (AFS) are complex multi-actor and multi-resource systems that are continuously adapting and evolving. Changes in them can be attributed to the adjustments in their components and interactions between them along with the external drivers like climate change. Additionally, governance strategies also influence the trajectory of change in these systems. In this paper, we critically explore how governance of agri-food systems (AFS) is intricately intertwined with gender and other social dynamics further affecting the way they transform.

Gender, often intersecting with other domains of disadvantage, such as poverty, caste, ethnicity, age or life-cycle affects the access and control over resources and the development outcomes in AFS. For instance, women, despite their integral role in influencing the transformation pathways in AFS, rarely participate in the governance processes. Their participation or perhaps a lack of it remains largely an outcome of prevalent gender norms and structural inequalities.

Evidence shows that for ensuring inclusive transformation of agri-food systems, integrating gender and social equity considerations into institutions, policies, and programmes remains essential. Such integration requires a paradigm shift in the global governance scholarship that could divert the focus towards actor interactions, identifying opportunities within governance spaces at different levels, and emphasising the role of policy language. Thus, by examining the critical role that different governance arrangements play in influencing the AFS sustainability and gender equality goals at various scales, we explore the evolving discourse on inclusive and equitable governance strategies. Through qualitative evidence synthesis, our main aim is to comprehend the interrelationship between gender, governance, sustainability, and agrifood systems. We also argue for a more nuanced lens for understanding and adopting governance strategies that enhance the existing knowledge systems and practices and can work towards making them more sustainable and resilient. The paper addresses the key question of "How gender equality lens in governance can facilitate equitable and sustainable transformations in agri-food systems?" This discussion significantly contributes towards understanding the diverse contextual perspectives in natural resource and food systems governance.

Keywords: Agri-food systems, gender, governance, social equity, socio-ecological systems, transformation

Contact Address: Kritika Goel, International Rice Research Institute, Evidence Module, CGIAR Gender Impact Platform, 340/c Saheed Nagar, 751007 Bhubaneswar, India, e-mail: k.goel@irri.org

Inclusion of gender and intersectionality in land, food and climate change policy: A feminist institutional approach

Fanny Howland, Maria Blanco, Diana Lopera, Alexander Buritica

The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact (PISA4IMPACT), Colombia

Although progress in promoting gender equality within governments has garnered attention; gender and intersectional disparities in national agrifood and climate policies persist largely unaddressed. Recognizing the imperative of adopting an intersectional gender lens in policy assessment becomes paramount, as policies blind to gender considerations tend to cater primarily to the needs of men and dominant social groups, neglecting the diverse needs of women and marginalised populations. In this context, Colombia emerges as a compelling case study for addressing gender and intersectionality (G&I) integration in policy. With its international commitments and existing gender policies at national and sectorial levels (e.g., agriculture), the country is primed for transformative mainstreaming. However, despite these promising foundations, limited research has been conducted on the extent to which G&I are included into the climate, land, and agri-food nexus. This study aims to bridge this knowledge gap through an innovative methodology for assessing G&I integration within Colombia policies, drawing upon three key approaches and concepts: gender and intersectionality, gender inclusion, and feminist institutional framework. Our three-step method involves mapping and prioritising relevant policies and actors, analysing fifteen (15) policy documents related to food, land, climate change, and gender, and conducting discourse analysis through twenty-eight (28) semi-structured interviews. Findings from the policy document analysis indicate that while land policies incorporate some G&I considerations, food policies tend to portray women stereotypically as mothers, prioritising children's rights over women's. Similarly, the technical approach to climate change often overlooks social aspects, resulting in limited G&I inclusion. Discourse analysis supplements these findings, highlighting factors constraining G&I inclusion, such as the wide gaps between social groups where G&I factors (gender, ethnicity, geography, age) combined exacerbate inequalities and a weak institutional gender position. Transversal issues like the sexist nature of the agricultural sector, the care economy invisibility, and the Colombian armed conflict further hinder G&I integration across land, food, and climate policies. Results suggest that strong international cooperation, the Peace Agreement, the role of women's social movements and the political will of the left-wing government create a historic window of opportunity for G&I inclusion in policy. These findings provide evidence for informed policymaking.

Keywords: Agri-food policies, Colombia, discourse analysis, gender mainstreaming, intersectionality, policy integration

Contact Address: Maria Blanco, The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact (PISA4IMPACT), KM 17 Recta Cali Palmira, 760050 Cali, Colombia, e-mail: maria.blanco@cgiar.org

Participatory rangeland management: Understanding women's engagement and implications for social change

Renee Bullock¹, Philip Miriti¹, Diana Lopez²

¹*International Livestock Research Institute (ILRI), Kenya* ²*Royal Tropical Institute (KIT), The Netherlands*

Climate change impacts severely affect livestock production systems in East Africa and elsewhere. Efforts to enhance resilience and capacities to anticipate, cope with, and recover from climate impacts will be essential to sustain livestock dependent communities. Gender roles in pastoral systems across East Africa are changing. Such shifts require more attention to understanding emerging opportunities for women to engage in rangeland governance institutions. Our purpose is to better understand women's engagement in participatory rangeland management (PRM) processes and implications for broader social change, that refers to changes in women's agency in rangeland institutions and the wider community. We drew upon qualitative data collected through key informant interviews, focus group discussions and semistructured interviews, in Baringo County, Kenya. We adapted and used a participation framework to analyse women's participation in rangeland activities, institutions and the household, to better understand implications for transformative agency. Overall, we found that women meaningfully participated in different aspects of PRM processes while changes in intra-household decision-making were fewer. PRM has increased women's voice and agency in governance of rangeland resources and potential to benefit from rangeland resources. Participation in multiple PRM activities reinforced women's agency in pastoral rangeland institutions in diverse contexts. Women's inclusion in rangeland management institutions has the potential for strategic and measurable impacts upon women's time and labour allocation. Multiple challenges however persist and include social norms and practices that hinder women's opportunities to leave their homes. Intersectional analyses into understanding adaptation to climate change and opportunities for socially inclusive efforts to enhance resilience are recommended.

Keywords: Adaptation, community, Kenya, pastoralist

Contact Address: Renee Bullock, International Livestock Research Institute (ILRI), 219 Loresho Crescent, 00100 Nairobi, Kenya, e-mail: r.bullock@cgiar.org

Gender mainstreaming in sustainable land and water management: Insights from the Lake Victoria Basin

Immaculate Edel¹, Sylvia Tramberend²

¹*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya*

²International Institute for Applied Systems Analysis, Water Security Group, Biodiversity and Natural Resources Program, Austria

Gender mainstreaming is crucial for sustainable development, particularly in complex regions like the Lake Victoria Basin (LVB), where gender disparities intersect with land and water resource management challenges. Despite the existence of national gender mainstreaming legal and policy frameworks in the LVB, there remains a gap in understanding their operationalisation, implementation, and effectiveness at the organisational level. In this diagnostic study, we assess gender mainstreaming efforts among selected land and water management organisations in the LVB, specifically Kenya and Uganda in East Africa. We also investigate barriers and enabling factors to successfully implement organisational gender strategies. We collected data from a sample of 32 purposefully selected organisations, representing various sectors including local non-governmental organisations, government departments, research institutions, civil society organisations, academia, international institutions, and the private sector. A questionnaire was used as the tool for data collection. Findings reveal varying levels of gender mainstreaming among the selected organisations. Organisations with a completed and implemented gender strategy (n=22) attribute their achievement to leadership support, cultivation of staff ownership, and understanding of gender through regular gender training and hiring designated gender focal persons to advise and guide the gender mainstreaming process. Consequently, the impact was improved scaling and greater staff engagement. Conversely, barriers to developing and implementing gender strategies include unfamiliarity with gender issues, insufficient financial and human resources to invest in gender, and competing priorities. Recommendations to improve gender mainstreaming efforts in the LVB include harmonising gender mainstreaming policies at the regional level (East African Community), enhancing capacity building in gender across sectors, and involvement of men, women, and youth in promoting gender equality. Our observation of inadequate implementation of gender strategies provides evidence of the need for a more coordinated approach in gender mainstreaming efforts in the Lake Victoria Basin. This approach should emphasise strong leadership and commitment, inclusivity, designated gender focal persons, intentional resource allocation for capacity building, and the establishment of monitoring mechanisms.

Keywords: East Africa, organisational strategies, sustainable land and water management

Contact Address: Immaculate Edel, The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), United Nations Avenue Gigiri, Nairobi, Kenya, e-mail: i.edel@cifor-icraf.org

Why female farmers cannot farm their land to the full potential – intersectional causes for poverty

CAROLIN ROSENBERG

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

In Zambia, poverty and food insecurity are still mainly a rural phenomenon, with three-quarters of the poor living in rural areas. Almost half of Zambia's population depends on agriculture for their livelihoods, with around 98 % of all farms run by smallholder farmers, cultivating predominately less than 2 ha of land. Moreover, with almost half of Zambian farmers being female, Zambia is among the countries with the highest proportion of women in agricultural employment worldwide.

A team from INEF, University of Duisburg-Essen, conducted focus group discussions with male and female farmers in Eastern Province. The aim of the study was to analyse the situation of smallholder farms, their needs, and the challenges they face. In line with the findings of previous studies conducted by the INEF team in Ethiopia, Benin, and Cambodia, the study showed that secure access to land and long-term use rights are a fundamental prerequisite for rural livelihoods and key to food security. However, in order to fully exploit its potential, access to agricultural financing for investments in farm inputs and implements, sufficient time to carry out agricultural activities and an adequate labour force are required. Yet gender-specific discrimination structures in Zambia, a country that is still strongly patriarchal, put women at a considerable disadvantage compared to their male counterparts in this respect. In addition to the double burden of unpaid domestic and care work, women in Zambia are significantly disadvantaged in terms of access to credit and mechanised equipment. Lacking decision-making power within the household, further contributes to them being side-lined. As a result, female farmers, especially single women, are less productive, affecting negatively their household income and food security.

The contribution aims to present the case study's findings with regard to the specific challenges female smallholder farmers in Zambia face. It further explores pathways to promote women's agricultural activities in Zambia and beyond.

Keywords: Agricultural finance, gender inequalities, intersectionality, land, smallholder farmers, Zambia

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

Fostering indigenous stewardship: Towards decolonizing natural resource management in southern Africa

CHARITY MASOLE, MARTIN PETRICK

Justus Liebig University Giessen, Agricultural Policy and Market Research, Germany

Community-based conservation (CBC) gained prominence in the 1960s at the end of Western colonisation of Africa as resource-rich former colonies sought to depart from Western approaches to natural resource conservation. The Western approach predominantly separated humans from nature, often marginalising indigenous communities and undermining their agency over resource management. Decades later, Community-Based Natural Resource Management (CBNRM) schemes pioneered in Southern Africa are criticised as being 'neo-colonialist', 'green colonialist', and 'captured by elites' in nature.

In this study, we seek to analyse challenges hindering equitable distribution of benefits from natural resource conservation among local communities as well as the communities' capacity to conserve natural resources. To this end, we collected data from four CBNRM sites in Botswana, Zimbabwe, and Namibia from October 2023 to March 2024. We conducted key informant interviews with natural resource management experts from academia, government, NGOs, and local conservation groups. Additionally, we obtained observational data from attending two annual general meetings of conservation groups in Namibia and Botswana during our fieldwork.

We find that communities across the three countries perceive CBNRM as being dominated by their governments and private companies. Additionally, they perceive benefits from conservation efforts as accruing mostly to private companies, the majority of which are operated by Europeans, while the communities shoulder the costs of conservation through high incidents of human-wildlife conflicts. The communities generally see themselves as having limited influence over the distribution of conservation benefits. Additionally, the communities expressed worries about the potential loss of their livelihoods should European countries ban imports of trophies from licensed hunting from the three countries.

Our findings underscore the importance of adopting a decolonial approach and empowering communities to participate actively in conservation efforts in the region. Measures such as integrating indigenous knowledge in conservation efforts and traditional practices such as the bow and arrow for hunting; sharing gains from conservation more equitably; actively engaging communities in addressing human-wildlife conflicts and poaching; and increasing community operation of hunting ventures and safaris could improve local agency in resource conservation. A bottom-up approach could foster synergies between local communities and other stakeholders in CBNRM.

Keywords: Agency, CBNRM, community-based conservation, decolonisation, southern Africa

Contact Address: Charity Masole, Justus Liebig University Giessen, Agricultural Policy and Market Research, Senckenbergstraße 3, 35390 Gießen, Germany, e-mail: gabanthate.charity.masole@ag.uni-giessen.de

A systematic review of gender-responsive social learning research in agriculture and natural resources management in Africa

Peter Asare-Nuamah¹, David Anaafo², Tina Beuchelt¹, Constance Akurugu³

¹University of Bonn, Center for Development Research (ZEF), Germany ²West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Interfaces, Burkina Faso ³Simon Diedong Dombo University of Business and Integrated Development Studies.

³Simon Diedong Dombo University of Business and Integrated Development Studies, Ghana

Addressing gender inequality is essential for sustainable development. Hence, contemporary research and development approaches, particularly implementation research, emphasise the need to adopt a gendered approach. Participatory social learning therefore offers a unique opportunity for engendering development approaches as it provides a common platform for diverse stakeholders to co-develop and implement collective actions for development. Given the vulnerability of the African continent coupled with the complex system of development, participatory social learning is gaining traction as an approach to both address gender inequality and advance collective development, especially in agriculture and natural resource management. However, to what extent are existing research in agriculture and natural resources management participatory and how do they address gender issues in their approaches. This study adopts a preferred reporting items for systematic review and meta-analysis (PRISMA) to explore the growth trajectory of participatory social learning research in agriculture and natural resources management in Africa and the approaches adopted to integrate gender in collective learning. Guided by the PRISMA guideline, the study used Web of Science and Scopus databases for the search and retrieval of 121 documents. The trend analysis shows an exponential growth in social learning research in Africa since 1979, peaking in 2019. Diverse approaches are adopted although many studies explored gender from a binary perspective mainly due to the data collection procedure. Studies that provide space for social learning for diverse stakeholders, especially workshops, are better suited to address and integrate gender and intersectionality in collective development. We recommend research and development efforts in agriculture and natural resource management in Africa to go beyond mere male and female analysis in promoting collective and collaborative development.

Keywords: Collaborative governance, gender, implementation research, social learning, sustainable development

Contact Address: Peter Asare-Nuamah, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, Bonn, Germany, e-mail: pasarenu@uni-bonn.de

Unpacking 'indigenous women's knowledge': Perspectives on gender and intersectionality in Food-Land-Water systems governance

Benu Verma, Kritika Goel, Saee Pawar

International Rice Research Institute (IRRI), India

Making 'indigenous women's knowledge' the focal point for policies and programmes on sustainable development and building climate resilience of Food-Land-Water (FLW) systems in the Global South, has emerged as a buzzword in the international development discourse. While indigenous knowledge on the ecosystem, especially farming practices, forests, health and medicine systems is a truism, the attention it has received uncritically takes women's knowledge and experience as given, regardless of their positionalities and contexts. Such orientation towards indigenous knowledge casts it in an ahistorical, apolitical light, assuming that the indigenous knowledge system is rigid and not constantly evolving and adapting. It also assumes that the 'indigenous', particularly 'indigenous women' are a homogenous group without any subjective differences. This paper is based on a qualitative study conducted in India on women land rights using ethnographic methods. The paper questions the orientation and impact of a certain kind of developmental thrust on gender and intersectionality in contemporary FLW systems research and governance of resources, particularly land. The experiences of women as well as men are defined by their subjectivities, social positions, ascribed gender roles, aspirations and knowledge production processes in their living environments. A unidimensional impetus on a rigid and unchanging knowledge system challenges the core idea of gender justice which is based on the principles of inclusion and diversity. This paper examines indigenous women's relationship with land through two case studies from the Indian context and unpacks the means of access and control practices exercised by women in governance of land. We also discuss the role played by the interventions of civil society organisations in shaping the land governance strategies by women. We explore and examine the pathways through which women access information and knowledge for developing more sustainable and resilient governance strategies. We further argue that pursuing sustainable development goals for women's empowerment and resilience in the FLW systems while working within an essentialised gender framework will have limited positive impact. A sensitivity and responsiveness to knowledge production processes, contextual gender and power relations could help create inclusive and adaptable development interventions and governance frameworks.

Keywords: FLW systems governance, gender, indigenous knowledge systems, intersectionality

Contact Address: Kritika Goel, International Rice Research Institute, Evidence Module, CGIAR Gender Impact Platform, 340/c Saheed Nagar, 751007 Bhubaneswar, India, e-mail: k.goel@irri.org

Advancing equitable distribution of benefits in restoration initiatives - can mobile money play a role?

NADIA GUETTOU DJURFELDT, BALENTINE OINGO, CHRISTOPHER KETTLE

The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behavior & Multifunctional Landscapes, Kenya

This study investigates links between gender norms in land tenure and tree planting practices, as well as mobile money usage for equitable distribution of benefits in restoration. The study's specific objectives are to: understand gender norms surrounding the land tenure system; investigate preferences for tree planting among different genders and age groups; and understand gender differences in mobile money access and use. Data was collected through 12 FGD and 6 KII in Turkana, Siaya, and Laikipia, Kenya. A total of 52 men and 55 women participated in the study. Results show that women younger than 35 years have the least access to community and individual land. Sharecropping is used by women to reduce risks and gain access to land through group leasing or borrowing. Although this can boost women's bargaining and decision-making power, the temporary nature of these land agreements restricts women's engagement in long-term activities like planting trees. Community members plant trees for different reasons, and results show that young women are particularly interested in food trees, while men of all ages do not prioritise these types of trees. Despite the involvement of older women in tree planting, men primarily make the decisions regarding income. In some cases, older women control ßmall income from sales of fruits, while "bigger amounts" are controlled by men. Young men and women use mobile money more often than the older generation. Lack of phone skills, access to mobile phones, and transaction fees are all barriers to use that affect older women more than other groups. However, community members find mobile money services convenient, helping users save money, and provide privacy, especially for women. Despite the gendered barriers women face in tree planting, there is evidence suggesting that some collective actions set in place by women, such as sharecropping, can serve as a strategic avenue to overcome certain barriers. Women's access to personal mobile phones and adequate skills to operate them appear to be critical to enhancing privacy and reducing the risk of external control over women's income, hence increasing the equitable distribution of benefits from restoration activities.

Keywords: Gender, Kenya, Laikipia, land tenure, mobile money, resilience

Contact Address: Nadia Guettou Djurfeldt, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behavior & Multifunctional Landscapes, Kaserani road icipe complex, 00621 Nairobi, Kenya, e-mail: n.guettou@cgiar.org

Motivations for agripreneurship among agro-pastoralist women in the district of Nikki (northern Benin)

Georges Djohy, Toussaint Koutchoro University of Parakou, Nat. School of Statistics, Planning and Demography, Benin

Agricultural entrepreneurship is being promoted in West Africa as the solution to food insecurity and unemployment among youth and women. Faced with food insecurity, high food prices, job insecurity, youth unemployment and increasing youth delinquency, Benin government has opted to promote and develop agricultural entrepreneurship. However, the efforts made with the support of international partners are often hampered by challenges such as identifying the entrepreneurial idea, predisposition to learning and risktaking. This study aims to analyse the factors that motivated women in the agro-pastoralist communities in the Nikki District (Northern Benin) to take up farming, with a view to informing policies geared towards agricultural entrepreneurship among young people and women. A mixed methods approach was used to collect quantitative and qualitative data from 140 snowball sampled female agricultural entrepreneurs, which was analysed using content analysis and descriptive statistics. Results showed that women agropastoral entrepreneurs are young (33 years old on average), educated or not (50.0 % non-literate, 31.4 % educated and 18.6 % literate) and mostly married (94.3%). They have set up individual and generally informal agricultural micro-enterprises with a maximum capital of XOF 150,000 (€ 229), from personal savings (70.3%), loans from micro-finance institutions (21.0%), donations (5.0%) or aid from development structures (2.9%). Women's microenterprises have a lifespan of 1 to 20 years (90.7%), and were inspired by old family activities (52.9%) or created on personal inspiration (47.1%). They mainly specialise in agri-food processing (40%) and cropping (23.6%), or combine several activities, including cropping, processing and marketing of raw or processed plant, animal, fish or forestry products (36.4%). Rural women were mainly extrinsically motivated to undertake farming for financial security (96.4%), personal pride (95.7%), social prestige (85.7%) and availability of opportunities (59.3%). The few cases of intrinsic motivation found among women relate to acquiring skills (95.0%), learning (90.7%), discovering (90.0%), and meeting societal challenges (80.7%). These findings are useful in informing policies to promote women's entrepreneurship and gender equality for sustainable livelihoods.

Keywords: Agripreneurship, agro-pastoralist community, motivation, women

Contact Address: Georges Djohy, University of Parakou, National School of Statistics, Planning and Demography (ENSPD), 03 BP 303, Parakou, Benin, e-mail: gdjohy@gmail.com

Exploring perceptions of land tenure security and its implications in northern Benin

Mélika Kèmi Vodoun
hessi 1,3 , Christoph Gornott 2,3 , Kisito Gandji
1, Kwame Hackman 1 , Lisa Murken 3

¹West African Science Service Centre on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso

²University of Kassel, Fac. of Organic Agricultural Sciences, Germany ³Potsdam Institute for Climate Impact Research (PIK), Germany

Land tenure security is a fundamental aspect of agricultural development, influencing farmers' decisions regarding investment, and their livelihoods. While numerous studies have examined the impacts of secure land tenure on agricultural outcomes, there remains a notable gap in understanding the nuanced consequences associated with farmers' perceptions of land tenure security, particularly in the context of Northern Benin. This study aims to address this gap by investigating the local perceptions of land tenure security and its effects across various socio-demographic groups in the region. The study is conducted in ten villages in the departments of Borgou and Donga, selected for their agricultural significance and the presence of migrant communities. A total of 300 households is surveyed using a digitalized questionnaire and an innovative tool called M-Tool, designed to collect and analyse mental models' data. Four distinct groups of farmers — men, women, migrants, and non-migrants — are targeted, ensuring representation across different demographic groups and age.

The results showed an assessment of local perceptions regarding the impacts of land tenure security, identification of socio-demographic factors shaping these perceptions. Through comparative analysis across various categories of farmers, this study unraveled the multifaceted nature of land tenure security and its implications for agricultural development in Northern Benin. The insights from this research will allow the formulation of equitable and sustainable land management policies tailored to the specific needs and challenges faced by rural communities in the region. This study represents a crucial step towards fostering a comprehensive understanding of the implications of perceived land tenure security, thereby facilitating the design and implementation of interventions aimed at enhancing agricultural production, livelihood resilience, and community well-being in Northern Benin.

Keywords: Farmers' perception, mental model maps, rural communities

Contact Address: Mélika Kèmi Vodounhessi, West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL), Ouagadougou, Burkina Faso, e-mail: vodounhessi.m@wascal.org

Conflict dynamics and opportunities for rural women's associativity under agroecological production schemes in Nariño Colombia

Pedro Pablo Bacca Acosta, Lizeth Tatiana Luna Mancilla, Marcela Elizabeth Riascos Delgado, David Eduardo Alvarez Sanchez, Jeisson Rodriguez Valenzuela, Jhon James Borja Tintinago, Roberto Argoti Eraso, Jose Luis Benavides Castro

Colombian Corporation for Agricultural Research, Obonuco Research Centre, Colombia

Food shortages are increasingly common in capital cities, even in rural areas suitable for agricultural production. Thus, environmental, economic, or social factors can cause this phenomenon. A common overview for many peasant communities represented by rural women in Latin America and the Caribbean is the lack of associativity, which can affect food production, marketing, and self-consumption. For this reason, this study seeks to analyse the implementation of a project aimed at strengthening the food and nutritional security of rural women of Obonuco in Pasto (Nariño), where technologies were adopted to promote the clean and healthy crop production (vegetables, legumes, aromatic and medicinal plants) and minor livestock species (chickens and guinea pigs). During the execution of the project, changes were evident in the dynamics of teamwork, commitment, and communication by two associative groups of 25 women (each), to carry out the establishment of agroecological gardens, agriculture modules in reduced spaces, awareness for healthy eating and strategies of short marketing circuits. After implementing a SWOT analysis through participatory workshops aimed at the rural women of this project, it was possible to identify land and water use conflicts, a high lack of confidence in working jointly using common goods, and resistance to transfer the ancestral knowledge by some women. Although these problems have a complex historical, cultural, and environmental background, which originates from previous generations and could weaken collective action and the social fabric of the territory, it is worth highlighting the commitment and motivation of most of the members to adopt the knowledge acquired during the execution of the project. However, even though the findings of this study confirm that associativity can be an opportunity to make this community more resilient to food and nutritional insecurity, it is necessary to study its grassroots conflicts to develop strategies to improve cooperative work.

Keywords: Co-innovation, female farmers, food security, peri-urban agriculture

Contact Address: Jeisson Rodriguez Valenzuela, Colombian Corporation for Agricultural Research, Obonuco Research Centre, Pasto, Colombia, e-mail: jerovagro@gmail.com

Climate change and food security disparities through a gender-specific lens: An agroforestry systems analysis in multiple countries of Africa

Zerihun Amare¹, Bernhard Freyer², Adama Oueda³

¹Bahir Dar University, Institute of Disaster Risk Management and Food Security Studies, Ethiopia

²BOKU University, Div. of Organic Farming, Austria ³University of Ouahigouya, Burkina Faso

Food security and climate change have strong gender and equity dimensions. Globally, women play a key role in food security. Climate change impacts vary among diverse social groups depending on age, ethnicity, gender, and wealth class. The climate change and food security disparities through a gender-specific lens study was conducted in Ethiopia (Zege catchment), Zimbabwe (Upper Save catchment), and Burkina Faso (Nakambe catchment). The study employed a quantitative approach complemented by qualitative methods, including key informant interviews and focus group discussions. Several priority problems were identified and a significant number of households in Zege, Nakambe, and Upper Save do not cover their household food consumption from crop production. The result findings in the study areas showed that households rely heavily on perennial cash crops rather than annual crop production. Exposure indicators in Zege, Upper Save, and Nakambe, and sensitivity indicators in Zege and Nakambe show statistically significant and high correlation with vulnerability. In the Upper Save, adaptive capacity and exposure are also statistically significant and highly correlated with vulnerability. Vulnerability levels of the Nakambe are very high compared to the Upper Save and Zege. Female-headed households had a statistically significantly lower vulnerability index compared to males in Zege, while male-headed households had a statistically significantly lower vulnerability index compared to females in Upper Save and Nakambe. The reason is land certification in Zege is higher than in the Upper Save and Nakambe. Agroforestry practices varied across the study catchments had statistically significant contributions to households' adaptive capacity. Besides, the agroforestry system is common in all catchments. Although their level of participation is varied, female-headed households in all catchments practised agroforestry management activities to adapt to climate change. We conclude that agroforestry practices do have substantial benefits in increasing women's adaptive capacity and reducing their vulnerability to climate change and food insecurity.

Keywords: Agroforestry, climate change adaptation, factor analysis, food security, gender, sub-Saharan Africa

Contact Address: Zerihun Amare, Bahir Dar University, Institute of Disaster Risk Management and Food Security Studies, Zenzelima Street, 3540 Bahir Dar, Ethiopia, e-mail: zerihun.yohannes19@gmail.com

Gender perspectives in Colombian public policy: Analysing impact and investment for equitable development

Fanny Howland, Diana Lopera, Maria Blanco

The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact (PISA4IMPACT), Colombia

Colombia has recently experienced a surge in public investment initiatives addressing gender disparities. This study comprehensively analyses gender-centric public investment projects in Colombia, delineating prevailing trends and assessing their impact on gender parity. Notably, a substantial concentration of these initiatives is found within the 'Social Inclusion and Reconciliation' sector regarding quantity and financial allocation. Our analysis reveals geographical variations, with specific regions at the departmental level emerging as focal points of gender-inclusive investment. Leveraging this geographical diversity and the institutional integration of the gender marker in national-level investment projects, our study evaluates the effectiveness of intervention strategies across various societal well-being indicators. We investigate the impact on indices related to crimes against freedom and sexual integrity during conflict development, physical injuries, minors' engagement in collective activities, and financial support to producer associations in municipalities within high-volume gendermarked investment departments. Employing an econometric event study framework, we compare municipalities within and outside these departments from 2010 to 2021, before and after 2019. Our findings suggest no discernible differences in outcome variables between the two groups of municipalities before intervention implementation. However, post-intervention, treated municipalities exhibit a notable decrease in various forms of violence, particularly significant reductions in crimes against freedom and sexual integrity during conflict periods. Regarding credit allocation, while a slight increase is observed in credits to small producer associations post-intervention, this change lacks statistical significance. Conversely, a significant decrease in overall credit allocation post-intervention, particularly immediately following the intervention, is noted. In conclusion, while gender-centric public investment projects in Colombia show promising results in reducing certain forms of violence, such as crimes against freedom and sexual integrity during conflict periods, further research and policy adjustments are necessary to optimise the allocation of financial resources and ensure comprehensive gender equality outcomes across all targeted indicators.

Keywords: Event study, gender, impact assessment, public investment

Contact Address: Fanny Howland, The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact (PISA4IMPACT), Cali, Colombia, e-mail: f.c.howland@cgiar.org

Intra-household gendered division of labour and time-use patterns: Implications for farm outcome and well-being in rural Ethiopia

Manale Andargie Embiyale

Justus-Liebig University of Giessen, International Ph.D. Program in Agricultural Economics, Bioeconomy and Rural Development (IPPAE), Germany

The Ethiopian economy and the livelihood of its population heavily rely on smallscale, traditional, and rain-fed agricultural endeavours. However, agriculture is more than just an economic activity in Ethiopia; it is a blend of socio-cultural aspects that shape farming practices. Retrogressive gender norms, for instance, delineate activities along gender lines. Notably, the word 'farmer' is linked to the male gender, while women are treated as servants of 'real farmers'. This cultural marginalisation is particularly prevalent in rural areas with limited infrastructure and educational facilities, affecting both farm practices and individual well-being. Therefore, investigating intrahousehold gender relations in terms of labour division and sharing of household responsibilities is crucial for rural sustainability, as emphasised in the 2030 Development Agenda (SDG5: Target 5.4). To explore these gender dynamics, a mixed-methods survey was conducted to gather both quantitative and qualitative data. Employed multistage random sampling to survey 400 farmers through face-to-face interviews using structured questionnaires, supplemented by six group discussions with eight participants each. Then the data analysis adopted a convergent mixed approach, triangulating both databases descriptively through a side-by-side comparison. The findings underscored that the restriction of tasks by gender, wage gap by gender, drudgery and associated illness, exclusion of women from traditional cooperatives, and religious restriction to work significantly affect farm activities and individual well-being through hindering potential labour force and disproportionately burdening women. Owing to women's household chores, they are also excluded from extension activities, thereby affecting the implementation of improved farm techniques. The regression analysis also reveals that factors such as receiving gender training, having elderly dependents, and longer marital duration positively affect farm outcomes, while having young children and housework time exert a negative impact. However, variables such as family size, farm size, education, leadership roles, and owning a radio are not statistically significant factors for farm outcome. In conclusion, this study advocates for policy interventions aimed at promoting gender equality, challenging traditional gender norms, and providing access to education and resources to foster a more equitable and productive agricultural sector in Ethiopia.

Keywords: Ethiopia, farm practices, intra-household gender relation, time-use pattern

Contact Address: Manale Andargie Embiyale, Justus-Liebig University of Giessen, International Ph.D. Program in Agricultural Economics, Bioeconomy and Rural Development (IP-PAE), Unterhof 61, 35392 Giessen, Germany, e-mail: manale.embiyale@agrar.uni-giessen.de

Analysing the gender equality discourse in Austrian agriculture applying a feminist political ecology lens

Annette Braun, Charlotte Voigt, Barbara Stadlmayr, Stefanie Lemke BOKU University, Sustainable Agricultural Systems, Austria

Even though gender equality has gained increasing attention in Austrian agricultural politics over the past decades, the agricultural sector remains a maledominated sphere. Gender disparities are reflected, among other aspects, in underrepresentation of women in agricultural organisations, low levels of female farm ownership as well as unequal division of unpaid care work. Language is a powerful tool for communicating ideologies, beliefs and values. To examine how language is used to address or maintain power structures, this study applies critical discourse analysis and uses a feminist political ecology lens. In particular it examines how the discourse on gender equality influences, and is influenced by, unequal gendered power relations in the Austrian agricultural sector.

For the critical discourse analysis, documents of two Austrian farmer organisations were examined that actively promote women in agriculture: ARGE Österreichische Bäuerinnen and ÖBV Österreichische Berg- und Kleinbäuer innen Vereinigung. Texts analysed include press statements, chartas, manifestos, position papers and letters to political representatives. These public documents were chosen based on their outward orientation to communicate the organisations' political viewpoints and demands. The timeframe of analysis is 2016 to 2024. This critical discourse analysis serves to explore how the two organisations conceptualise gender equality and how they seek to support the transition to a more gender-equal agricultural sector in Austria. Preliminary findings indicate that the ÖBV understands gender equality as a wider and more inclusive concept by also integrating an intersectionality perspective, taking into account other social categories besides gender, and queer ecologies. Furthermore, ÖBV makes use of gender-sensitive language in all their internal and public documents. The ARGE, on the other hand, has a more conservative conceptualisation of gender equality. This is revealed, for example, by their focus on the gender binary of male and female.

If gender equality is taken seriously at all levels – the political level, public discourse, farmers' associations, farm and household level - and grounded in a feminist political ecology approach, this can help to address and overcome gender inequalities in the agricultural sector in Austria in the future.

Keywords: Agricultural politics, critical discourse analysis

Contact Address: Annette Braun, BOKU University, Sustainable Agricultural Systems, Felix-Dahn straße 10/7, 1180 Vienna, Austria, e-mail: annette.braun@boku.ac.at

Gender equity implications of the adoption of mechanised livestock fodder choppers in Bangladesh's mixed farming systems

Michael Euler¹, Stephanie Cheesman², Santiago Lopez-Ridaura², Mizanur Rahman², Farah Keya², Timothy J. Krupnik²

¹International Maize and Wheat Improvement Center (CIMMYT), Ethiopia ²International Maize and Wheat Improvement Center (CIMMYT), Bangladesh

Agricultural mechanisation has the potential to strengthen women's wellbeing and socio-economic status in agrifood systems. The net welfare effects of mechanisation on women farmers depends on intra-household gender relations which shape women's ability to seize associated reductions in drudgery and workload, and to influence decisions on the use of agronomic production surplus and income gains. However, the adoption of agricultural mechanisation may also directly influence women's empowerment and intrahousehold bargaining processes, especially if gendered roles in management and decision-making are affected by the introduction of agricultural machinery. While gendered adoption determinants and socio-economic implications of the use of mechanisation services at the farm level have received some attention in recent literature, there is little empirical evidence on the impact of agricultural mechanisation on women's empowerment. In this study, we use data from 758 female and male farmers from Bangladesh to assess the correlates of the adoption of mechanised livestock fodder choppers on gendered time-allocation, participation in decision-making, and control over the use of livestock income. Using matching techniques to account for observed heterogeneity between fodder chopper users and non-users, we find that the use of fodder choppers is associated with time savings in livestock production, most of which is captured by women farmers. Saved time is used for leisure and resting, which may enhance women wellbeing. While we do not observe changes in gendered decision-making arrangements with the introduction of fodder choppers, we do find significant associations with gendered control over the use of livestock income, with husbands claiming more, and wives claiming less influence on the use of livestock income. We conclude that the gendered outcomes of the adoption of fodder choppers is context dependent and may come at the expense of women agency in livestock production.

Keywords: Bangladesh, livestock, mechanisation, women's empowerment

Contact Address: Michael Euler, International Maize and Wheat Improvement Center (CIM-MYT), Addis Ababa, Ethiopia, e-mail: m.euler@cgiar.org

Who gets the land? A comparative case study on "failed" large-scale land deals in Ghana

PROSPER LOH FUL, JOSEPHINE MONTFORD, CHRISTINE BOSCH, REGINA BIRNER University of Hohenhiem, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

Large-scale land deals in Africa have profound repercussions in many rural communities altering socio-economic frameworks and livelihoods even if they are non-operational or fail. Ghana is a case in point where according to the Land Matrix, more than 400,000 hectares were acquired for bioenergy crops, at the height of the "land grab" period. More than a decade later, many of these deals grow different crops, are only partially operational, nonoperational or have been given up completely.

These failed deals have rarely been studied and, therefore, it is unclear what happened to the land and its former users. We aim to provide an in-depth understanding of such land deals, the current land use, the institutional setting, and differentiated experiences of affected community members, such as landowners, migrant sharecroppers, and women. Two cases are selected which have been subject to an earlier study by one of the authors. We used a mixed-method comparative case study research design employing the Process Net-Map method, in-depth interviews, focus group discussions and transect walks for an in-depth exploration of the present state after the failed land deals. The revised 'Sustainable Livelihood Framework' by Scoones is combined with the 'Theory of Access' by Peluso and Ribot to interpret our findings. Results show rather different outcomes at the two sites with an important link between the present situation on these lands to the nature of the initial lease agreements. Case 1 is ongoing with different crops on a very small scale, and some parts of the remaining lands given to a few company workers who gained access to the land to maintain company control over it prospectively. In case 2 the company has completely abandoned the land, and members of the community including a large proportion of previous landowners' wives and migrant sharecroppers who were previously disenfranchised, are now allowed to farm the former company land under the auspices of the subchief. This study shows that land rarely returns to the original owners after a failed deal as in other literature and this have implications on sustainable land use and fairer redistribution prospects.

Keywords: Bioenergy crops, gendered experiences, land governance

Contact Address: Christine Bosch, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Wollgrasweg 43, 70599 Stuttgart, Germany, e-mail: christine.bosch@uni-hohenheim.de

Behaviour and attitude toward integrated pest management in Burkina Faso: A gender length perspective in the Cascade region

EVELINE MARIE FULBERT WINDINMI COMPAORÉ¹, NATEWINDE SAWADOGO² ¹Institute for Environment and Agricultural Research (INERA), Burkina Faso ²University of Thomas Sankara, Burkina Faso

Many of cowpea varieties are vulnerable to pest attacks in Burkina Faso. This has been a concern for many farmers who are desperately looking for solutions. So far, the impact of increased use of pesticides in agricultural production is consider as a threat to human and environmental health. Integrated Pest Management (IPM) is believed to be an alternative toward conventional pest management practices that conventional agriculture brought about. The implementation of such system that combines different forms of biological, cultural and chemical control, while minimising the use of synthetic pesticides face also multiple challenges especially in Burkina Faso despite efforts. Using the multidimensional project-level Women's Empowerment in Agriculture Index (pro-WEAI), this study aims at looking some of the 12 binary indicators, underlying count versions of 6 of these, an aggregate empowerment score (continuous) and a binary aggregate empowerment indicator, all for women and men. Women's and men's scores were compared to assess gender parity. The result shows that the challenges in implementing IPM programmes and adoption of IPM practices are closely linked to gender and socio-economic factors in addition to supporting policy at national level that could help make available ecological pest management products. The study conducted in the cascade regions shows that the nature of IPM remain manual and therefore requires more time and extra efforts and patience to cover a reasonable size of land. Women therefore, despite lack of training and knowledge are so far the champions in the use of such system on their small plots. The heaviness of the implementation of the system does not allow men to fully get involve in this. In addition, the challenges in IPM implementation have implications on the type of farming system taking into account the capacity of the farmer in terms of land size and manpower.

Keywords: Burkina Faso, gender, implementation, IPM

Contact Address: Eveline Marie Fulbert Windinmi Compaoré, Institute for Environment and Agricultural Research (INERA), 01 BP 476, Ouagadougou, Burkina Faso, e-mail: compeve@yahoo.fr
Strategies for implementing gender-transformative sustainable agricultural mechanisation within smallholder agriculture production

Selorm Y. Dorvlo¹, Elizabeth Mkandawire²

¹University of Ghana, Dept. of Agricultural Engineering, Ghana ²University of Pretoria, FSNet-Africa, South Africa

Agriculture is a vital industry that provides livelihoods to millions of people worldwide. The farming community relies on natural and man-made resources, such as land and farm machinery, to produce the food that sustains us. However, social and cultural norms surrounding agricultural production can result in an uneven distribution of essential resources necessary for sustainable agricultural mechanisation. Sustainable agricultural mechanisation (SAM) is a farming practice that uses appropriate machinery to remove drudgery, enhance agricultural production efficiency, and be economically and environmentally friendly. Promoting equality among farmers and advocating for SAM is crucial to ensuring fair and sustainable farming practices. Therefore, it is necessary to adopt gender-transformative approaches to promote inclusive and sustainable agricultural mechanisation. This will help remove gender barriers and support women, who play a crucial role in agriculture, in accessing and adopting mechanisation practices. Quantitative and qualitative data were used to understand gender dynamics in machinery acquisition, access, and utilisation by smallholder farmers in Asutsuare, Ghana. The study utilises quantitative data from 320 farmers and qualitative data from key informant interviews and focus group discussions to emphasise the need for a gender-transformative approach to sustainable agricultural mechanisation. The data analysis revealed differences in machinery access, intention to use machinery, and projected benefits among gender and age groups. The presentation presents a framework and strategies for promoting gender-transformative sustainable agricultural mechanisation and highlights their practical implications. These strategies foster gender equality, sustainable agriculture, and socio-economic and eco-friendly practices through mechanisation. The strategy and framework proposed, when implemented, will make significant strides towards a more equitable and sustainable agricultural sector.

Keywords: Agricultural production, gender-transformative agriculture, smallholder farmers, sustainable agricultural mechanisation

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

Equal benefits or not? Farmer perceptions of the cowpea living mulch technology in northern Ghana

Rashida Chantima Ziblila¹, Gundula Fischer², Kipo Jimah³, Nurudeen Abdul Rahman¹

¹International Institute of Tropical Agriculture, Mixed Farming Systems Initiative, Ghana ²International Institute of Tropical Agriculture (IITA), Africa RISING, Tanzania ³ACDI/VOCA, Market Systems Research, Ghana

Live mulch cropping systems improves soil fertility, yield productivity and smother weed growth. However, it increases labour demand for field activities such as planting and harvest in smallholder farms. Limited literature exists on the gender group who benefits the most from live mulch cropping systems in smallholder farms. A gender evaluation was conducted in 2019 to assess farmers experiences in relation to the benefits of the cowpea living mulch (CPLM) technology. The CPLM is the intercropping of cowpea at 1–2 weeks after planting maize as a living mulch for sustainable production of maize in smallholder farms. Twelve gender (6 female and 6 male) focus group discussions were held with 84 sampled African RISING farmers who validated the CPLM technology for two years (2017–2018). The ustainable Intensification Assessmentframework was used as a guide to assess the benefits of the CPLM technology across 5 domains (productivity, economic, environment, human and social). Drudgery scores and household members labour involvement at different cropping stages of the technology were also assessed through participatory scoring activities. Both male and female farmers perceived an increase in soil fertility (environment), cowpea consumption (human), income (economic) from CPLM than the maize monocrop. Whereas some farmers perceived maize yield to increase under CPLM compared to maize monocrop in the first season, others perceived maize yield increase after the first season of practicing the technology (productivity). While also recognising that weeding is done once in the CPLM relative to the twice weeding in the maize monocrop, farmers perceived the CPLM to be time-consuming and labour demanding during activities such as planting and harvesting, tasks that are often done by women and children. Despite the perceived benefits of the CPLM as highlighted above, it increases the labour burdens of especially women during planting (20%) and harvesting (13–33%) activities compared to that of men. We recommend the adoption of simple mechanised planters and harvesters to lessen the labour burdens of women farmers to enjoy the full benefits of the CPLM technology through it effects on environment, productivity, income, gender equity, food, and nutritional security.

Keywords: Cover cropping, gender, Ghana, perceptions, smallholder farmers

Contact Address: Rashida Chantima Ziblila, International Institute of Tropical Agriculture, Mixed Farming Systems Initiative, Gur 278 Gurugu, Tamale, Ghana, e-mail: r.ziblila@cgiar.org

Do attitudes of men and women towards gender equality affect women's economic empowerment?

Emmanuel Letaa, Bezawit Adugna Bahru, Manfred Zeller

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

The United Nations have identified women's economic empowerment as a critical component for achieving the Sustainable Development Goals. Changing attitudes towards gender equality has attracted the attention of policymakers and development practitioners as an important driver for improving women's economic empowerment indicators. Studies however have mixed results on women's economic empowerment indicators, depending on policies, laws, and institutions. Most of these studies focus on women's attitudes, particularly the wife in the household. Moreover, the studies measure women's economic empowerment in terms of labour force participation indicators such as wage employment, which are not common, particularly in rural areas where most women live. Using nationally representative time use survey data, this paper examines the impact of attitudes of men and women couples towards gender equality on women's time in market work and unpaid work, in Uganda. It uses an instrumental variable approach to account for potential reverse causality between attitudes and time use. We find that women have more gender-equal attitudes than men. Results of multivariate Tobit regression show that gender equality attitude of men (egalitarian attitude) is positively and significantly associated with women's time in market work. Similarly, gender equality attitude of men is negatively and significantly associated with women's time in unpaid work. However, we find no significant relationship between the gender equality attitude of women and their time in market work and unpaid work. We also find that personal time leisure, socialisation, and self-care are associated with women's time spent in market and unpaid work. Policies that aim to improve women's economic empowerment indicators should focus on changing men's attitudes towards equality.

Keywords: Attitudes, gender equality, Uganda, women's economic empowerment

Contact Address: Emmanuel Letaa, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Kampala, Uganda, e-mail: letaaem@gmail.com

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Multiple crises: political, institutional and economic structures and challenges

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Comparative study of regulation and certification policies on bioinputs in different tropical countries

Renato de Sousa Faria¹, Joao Asmar Junior², Alcido Elenor Wander³

¹Federal University of Goiás, Graduate Program in Agribusiness, Brazil ²Department of Agriculture, Livestock and Supply of the State of Goiás, Brazil ³Brazilian Agricultural Research Corporation (EMBRAPA), Brazil

The certification and regulatory frameworks for bioinputs are extremely important in tropical countries with regard to their mention. Though these policies help in protection of environment, public health and help bioinput product efficacy, safety, and quality. This paper compares the certification procedures and regulations for bioinputs in several tropical countries with an emphasis on the laws concerning biostimulants and biorational products. The research aimed to assess certification procedures and legal frameworks that were instituted in several tropical countries such as Nigeria, India, and Brazil. For instance, in Brazil, regulation on bioinputs falls under the Ministry of Agriculture, Livestock, and Supply. In this country, there exist stringent processes of registering these products, where bioinputs are even well outlined. The Ministry of Agriculture and Farmers Welfare in India is responsible for the regulation of bioinputs, while its Nigerian counterpart uses the National Agency for Food and Drug Administration (NAFDAC) and the National Agricultural Seeds Council (NASC) to regulate bioinputs. The whole country has come into force with Fertiliser Control Order, which has put regulations in place governing production, importation as well as distribution of bioinputs. These organisations ensure that bioinputs meet the criteria for being certified and registered. The study concludes that many similarities exist between the regulatory frameworks of certain countries while there are also significant differences. For example, in contrast to Nigeria and India, Brazil has stricter registration standards for bioinputs. Fertilisers require distinctive guidelines in Brazil while in India and Nigeria they are regulated under different set of rules. It also sheds light on the importance of certification processes in ensuring that bioinput standards are met. In as far as certification is concerned, certification bodies often utilise laboratory tests as well as field trials as part of quality assurance mechanisms for specific characteristics attributed with same products. The overriding objective of doing a comparative analysis is to show the how essential it is for tropical countries to have effective certification mechanisms and regulations for bio-inputs. For purposes of ensuring the effectiveness, safety and quality of the bio-inputs, tropical nations are supposed to develop or implement strong regulations and certification frameworks.

Keywords: Bioinputs, certification, regulation, sustainable farming, tropical agriculture

Contact Address: Alcido Elenor Wander, Brazilian Agricultural Research Corporation (EM-BRAPA), Rodovia GO-462, km 12, 75375-000 Santo Antonio de Goias, Brazil, e-mail: alcido.wander@embrapa.br

Assessing the contribution of climate-resilient UN shelters to humanitarian-development-peace outcomes in Mozambique and Pakistan

Adam Savelli¹, Shahab Khalid¹, Alessandra Vaselli¹, Grazia Pacillo², Peter Läderach³

¹The Alliance of Bioversity International & CIAT, Vietnam ²The Alliance of Bioversity International & CIAT, Egypt ³The Alliance of Bioversity International & CIAT, South Africa

In contexts affected by climate- and conflict-related displacement, the construction of temporary humanitarian shelters has long been a preferred method of humanitarian intervention by UN agencies and international organisations. However, as the average length of displacement has grown more protracted, shelters have evolved – in outcome, if not always intent – from short-term mechanisms of humanitarian response to longer-term communal formations. This evolution mirrors a discursive shift among UN agencies and international actors away from "simple" humanitarian responses, and toward those that simultaneously target humanitarian, development, and peace (HDP) outcomes. For shelters interventions, this has resulted in new strategic objectives that include sustainable development, climate action, and peacebuilding.

To explore how UN-led shelters interventions perform against these targets and identify ways that future interventions can better achieve their goals, this paper assesses and compares two ongoing climate-resilient shelter interventions: one led by UNHCR in Maratane, Nampula, Mozambique, and another by IOM in Mirpur Khas, Sindh, Pakistan. Maratane is Mozambique's sole official refugee encampment, and UNHCR is constructing several hundred climate-resilient shelters for host and refugee communities to replace housing destroyed by cyclone Gombe in 2022. Similarly, in Mirpur Khas, IOM is building approximately 500 shelters to replace housing destroyed by unprecedented flooding in 2022.

A mixed-method approach was employed to explore how each intervention has influenced humanitarian, development, and peace outcomes. Approximately 200 intervention participants that received shelters were surveyed at each site, while key informant interviews were convened with intervention participants, UN staff, and government officials.

Preliminary results show that while shelters performed strongly against humanitarian objectives, development gains were harder to identify. Concerningly, shelters seem to have had a negative impact on peace, with intra- and

Contact Address: Adam Savelli, The Alliance of Bioversity International & CIAT, Hanoi, Vietnam, e-mail: a.savelli@cgiar.org

inter-communal tensions increasing, trust and participation in local governance structures decreasing, and anti-UN sentiments increasing in their wake. Opportunities for improving future shelter interventions include increased community control and ownership of future interventions, implementing processes that support collective action and community dialog, and the mainstreaming of conflict-sensitive and peace-positive approaches.

Keywords: Development, displacement, host communities, shelter interventions, social cohesion

Repairing the mosaic: The political economy of landscape-level agroecological transitions

Sonali Singh, Ruth Meinzen-Dick International Food Policy Research Institute (IFPRI), India

Agroecology offers a promising pathway to enhance the resilience and fairness of agrifood systems by integrating ecological, social, and economic dimensions, prioritising natural processes, minimal external inputs, and participatory approaches. The social metabolism, or flows of materials and energy between nature and society, transcends boundaries of individual farms. In contrast to approaches that focus on plot or farm-level practices, landscapelevel agroecology seeks to integrate across landscape mosaics, including individual farms as well as forests, rangelands, wetlands, water bodies, and other forms of commons. This poses significant coordination challenges of achieving this interconnectedness in governance of land and natural resources, particularly related to land tenure and coordination of actors. This paper addresses how political economy affects the coordination challenges inherent in realising agroecological transitions at the landscape level. We employ the 31's framework of political economy, focusing on how the ideas, interests, and institutions of various actors shape landscape-level application of agroecology governance of land and natural resources, especially concerning tenure security. Through a case study from Mandla District, Madhya Pradesh, India, we delve into the power dynamics and institutional structures influencing landscape-level agroecology. Employing stakeholder analysis and case study methodologies along with key informant interviews and focus group discussions, we explore critical components of agroecological landscapes, such as actor coordination, commons management, collective action, social equity, and tenure security. Our findings underscore the importance of acknowledging the heterogeneity within and among stakeholder groups, particularly farm households and government agencies. We also identify processes to foster mutual understanding among stakeholders. We conclude by discussing the utility of the political economy framework in informing strategies for agroecological transitions and highlight the potential of the Indian experience to inform global efforts.

Keywords: Actor-coordination, agroecological transition, landscape-level, political economy, social metabolism, tenure security

Contact Address: Sonali Singh, International Food Policy Research Institute, Natural Resources and Resilience, 37-32 Old Rajinder Nagar, 110060 New Delhi, India, e-mail: sonali.singh@cgiar.org

Circular bioeconomy for sustainable resource management and livelihood improvement in Ethiopia

Susanne Bodach¹, Oluwadara Alegbeleye¹, Avinandan Taron¹, Fitsum Hagos²

¹International Water Management Institute (IWMI), Sri Lanka ²International Water Management Institute (IWMI), Ethiopia

Ethiopia faces a growing challenge of balancing natural resource utilisation with long-term sustainability. Its linear economic model leads to unsustainable waste generation from agriculture, urban populations, and the industry sectors. This paper explores the potential of a circular bioeconomy (CBE) as a solution. By promoting closed-loop systems that minimise waste and maximise resource use, CBE offers a pathway for Ethiopia to achieve sustainable resource management, economic growth, and better livelihood opportunities. CBE business models create valuable products such as organic fertiliser, biochar, bioenergy, and alternative proteins. CBE practices provide new income opportunities for farmers and urban dwellers and reduce the country's reliance on virgin resources, chemical fertiliser, and non-renewable energy while addressing environmental pollution and soil depletion.

Major organic waste streams in Ethiopia that could be recovered and reused include agricultural crop residues, animal manure, human excrement, and industrial sludge. Addressing the vast untapped potential of resource recovery from waste, this study analyses opportunities and challenges associated with promoting CBE in Ethiopia, focusing on analysing the regulatory framework, business licensing and registration procedure, government support, access to finance, and business support services. The paper employs a comprehensive desk review of peer-reviewed literature complemented by grey literature to capture recent trends or non-traditional research aspects. Semi-structured interviews with sector experts were conducted to fill information gaps.

Key findings of this study are that a robust regulatory framework, streamlined business registration, and access to finance are critical for creating an enabling investment climate for CBE. Government support, business networks, and support services can empower CBE ventures and contribute to sustainable resource management. By focusing on policy interventions that combine sustainable waste management and livelihood creation, CBE can significantly contribute to achieving a more sustainable development path for all Ethiopians.

Keywords: Bio waste, bioenergy, organic waste, policy recommendations

Contact Address: Susanne Bodach, International Water Management Institute (IWMI), 127 Sunil Mawatha Pelawatte, 10120 Battaramulla, Sri Lanka, e-mail: s.bodach@cgiar.org

Bridging the gap between agri-food policy and science in Kenya

Joseph Karugia¹, Michael Keenan², Grace Njoroge¹, Clemens Breisinger², Leonard Kirui³, Richard Ndegwa⁴, Joyce Maru³

¹International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Kenya

²International Food Policy Research Institute (IFPRI), Kenya

³International Potato Centre (CIP), Kenya

⁴Ministry of Agriculture and Livestock Development, Research, Kenya

Research-based evidence is not always put to full use by policymakers. The question of why this is the case has often been addressed conceptually with sparse efforts to collect real-world data from actors. This paper provides an in-depth analysis of the sciencepolicy interface (SPI) in Kenya using key informant interviews with Kenyan policy makers, researchers, and private sector actors. Several recommendations emerge on how Kenya can boost research impact by optimising existing institutions, structures, and resources. Aligning policies across ministries and utilising existing efforts like the "Presidential Economic Transformation Secretariat" can promote coherence and streamline research efforts. Initiatives like the "National Agricultural Research Systems Policy" for research coordination and "Global Open Data for Agriculture and Nutrition" for data can be leveraged to streamline collaboration. Public consultations, workshops, and conferences remain important mechanisms for researchers to engage policymakers and stakeholders throughout the policy cycle, from agenda setting to evaluation. In addition, closed-door meetings are crucial for policymakers navigating sensitive issues. These targeted sessions with experts offer a safe space for confidential information exchange and unfiltered advice. Building technical capacity in ministries and training researchers for policy engagement can further support effective policy formulation and implementation. A collaborative research agenda is also recommended. This requires government, private sector, and researchers to clearly communicate needs and priorities. Ideally, the government should take the lead in funding research to ensure it directly addresses policy needs. In the short term, however, collaboration between governments, researchers, and donors remains crucial to bridge the gap. Ideally, such funding is flexible to allow for addressing emerging issues and allow for timely responses. To incentivize more engagement, universities and research institutes should value policy work more and allocate funds to support researchers in engaging with policymakers. For improving the SPI at the national and county level, investing in data infrastructure is also critical, implying better farmer data collection, storage, and dissemination systems, along with creation of easily accessible data repositories. Clear data sharing protocols are needed between government, researchers, and the private sector.

Keywords: Kenya, key informant interviews, policymakers, qualitative data

Contact Address: Joseph Karugia, International Livestock Research Institute (ILRI), Policies, Institutions and Livelihoods, Old naivasha road, Nairobi, Kenya, e-mail: j.karugia@cgiar.org

Moving off the farm: Does farming efficiency matter? Insights from panel data for Thailand

KASEM KUNASRI, MANH HUNG DO, TRUNG THANH NGUYEN Leibniz Universität Hannover, Inst. for Environmental Economics and World Trade, Germany

As an essential part of economic growth, agricultural transformation is characterised by the reallocation of labour from farm to non-farm sectors. However, there is limited evidence on how farming efficiency affects the allocation of labour from farm to non-farm sectors at the household level. In this study, we explore the effects of farming efficiency on agricultural transformation and investigate the influence of farming efficiency on the shift from full-time to part-time farming at the small-holder farm level. We use panel data from the Thailand-Vietnam Socio-Economic Panel (TVSEP), a long-term project funded by the German Research Foundation, for empirical analyses. Our sample includes 10,549 observations collected in Thailand from seven survey waves between 2007 and 2019. We first estimate farming efficiency of rural households by employing a stochastic frontier model with true randomeffects and Mundlak's adjustments. Then, we employ a heteroscedasticitybased approach with instrumental variables to examine the effects of farming efficiency on six indicators of agricultural transformation, reflecting labour allocation, livestock development, and agricultural mechanisation. Our results reveal that farming efficiency positively and significantly affects the share of farm income, per capita income from farm activities, and per hectare expenditure on mechanisation. We also find that farming efficiency has a negative and significant effect on the share of non-farm income, per capita income from non-farm activities, and the share of livestock income in farm income. These results imply that more efficient farmers tend to stick to farming and apply mechanisation in crop production, while less efficient ones shift to non-farm sectors. The results remain consistent when we consider different levels of household's engagement in non-farm employment. Policies designed to support and encourage farm enlargement (increasing farm size) and labour allocation (less efficient farmers move to non-farm sectors) should be stimulated to accelerate agricultural transformation.

Keywords: Agricultural transformation, full-time to part-time farming, heteroscedasticity-based approach, instrumental variable

Contact Address: Kasem Kunasri, Leibniz Universität Hannover, Inst. for Environmental Economics and World Trade, Königsworther platz 1, 30167 Hannover, Germany, e-mail: kunasri@iuw.uni-hannover.de

A conceptual framework for agency and behaviour change in agri-food systems transformation

Rachel Voss¹, Sarah Freed², Anne Rietveld², Thomas Falk³

¹*The Alliance of Bioversity International & CIAT, Germany*

²The Alliance of Bioversity International & CIAT, Kenya

³International Food Policy Research Institute (IFPRI), Natural Resources and Resilience Strategies Unit, Germany

Agri-food systems reforms such as agroecology are receiving increased attention. However, adoption and scaling of agroecology has been limited despite growing investment, raising questions about effective behaviour change pathways for agri-food systems transformation. We argue that agroecological transition must be understood as a process of systems transformation, and propose a conceptual framework on agency and behaviour change for transforming agri-food systems (ACT). The ACT framework explores how agri-food system components beyond producer attitudes interact to shape actors' opportunity spaces, which create conditions for behaviour change. We identify economic, governance, resource, and social and relational subsystems as key structural elements shaping behavioural outcomes. The latter of these not only affects behaviour directly, but also mediates how other structural factors influence individual and collective power and agency, and therefore opportunity spaces, on the basis of actors' intersectional identities. We applied the ACT framework to analyse case studies of past agroecological initiatives developed through desk reviews, key informant interviews, and document analysis in India, Kenya, Peru, Tunisia, and Zimbabwe. Specifically, we investigated the common entry points that initiatives used to support agroecological transformation (i.e., target actors, behaviours, and behaviour change strategies) and the rationale for the chosen entry points as explained by initiative designers and/or understood by implementers. We found that historically, agroecologyrelated initiatives have had a heavy focus on producers' behaviour and sought to spur behaviour change by increasing producer knowledge. Attention to wider agri-food system actors has been limited, as well as engagement with economic, resource, governance, and social and relational subsystems. Better understanding the enabling and impeding factors in agroecological transformation requires attention to how the enabling environment creates opportunity for behaviour change and agency, and how diverse actors' experiences differ. We therefore find that the ACT framework can support clearer identification of target actors, behaviours, assumptions about those behaviours, and what role structural system elements play — and through that, the design of more effective, inclusive, locally driven agri-food initiatives.

Keywords: Agency, agroecology, behaviour change, conceptual framework, opportunity space, social inclusion

Contact Address: Rachel Voss, The Alliance of Bioversity International & CIAT, Mittenheimer Straße 19, 85764 Oberschleißheim, Germany, e-mail: rcvoss@gmail.com

A case study of the FARC peace agreement impact on land markets in Caquetá, Colombia

Manuel Moreno, Alexander Buritica, Deborah Pierce, Carolina Gonzalez, Augusto Castro

The Alliance of Bioversity International & CIAT, Colombia

Armed conflicts continue to take a huge toll worldwide, including in Colombia, where the government signed a peace agreement in 2016, ending more than 50 years of conflict. This research explores the relationship between conflict violence and land dynamics, including land use, economic valuation, and transactional patterns. Leveraging the Colombia peace agreement as a natural experiment, we investigate its impact on rural land transactions and deforestation, particularly focusing on 125 cattle farms in the Caquetá region. These farms have been categorised based on their proximity to highly conflictaffected areas. This allows for a comparative analysis of land transactions and deforestation rates before and after the signing of the peace agreement in the designated year. To conduct this analysis, we employ data from Certificates of Tradition and Freedom (CTL), which provide a comprehensive historical record of land transactions for each cattle farm from 1940 to 2023. Applying an econometric differences-in-differences model, we observe a decrease in rural land sale transactions within high-conflict areas following the implementation of peace agreement. Our findings underscore the pivotal role of policy changes in shaping the lives of individuals. This study can inform policymakers to foster societal transformation, poverty alleviation and sustainable natural resources management. In the future we expect to include results on the land use of each of these properties today, as well as different price sources on the valuation of the properties, including qualitative information on the subjective price of the land. With this information we expect to know how the impact of the conflict has impacts on land use and valuation today.

Keywords: Conflict, difference in difference, impact assessments, land

Contact Address: Manuel Moreno, The Alliance of Bioversity International & CIAT, Performance, Innovation and Strategic Analysis for Impact, Cra 7c 72a56, 760012 Cali, Colombia, e-mail: manuel.moreno@cgiar.org

Neocolonialism, empowerment or no big deal - Implications of new EU rules for organic group certification on third countries

Ohemaa Agbolosoo-Mensah, Tilman Reinhardt

University of Bayreuth, Fac. of Life Sciences: Food, Nutrition and Health, Germany

Organic farming is the only form of food production strictly governed by legislation that provides for stringent standards and robust control from farms to consumers. The EU organic sector has seen tremendous growth in recent years and is currently worth approximately €27 billion. The EU's Farm-to-Fork strategy, its Organic Action Plan and various national strategies have elevated the status of organic and support its development in the coming years. A significant share of the organic market comes from imported commodities such as cocoa that are grown by smallholders in countries of the global south. The rapid growth and increasing competition however have created challenges to ensure organic integrity and to uphold consumer confidence that is essential to justify the organic price premium. The new Organic Regulation (EU) 848/2018 which takes effect from January 1st 2024 inside the EU and from January 1st 2025 for third countries contains several provisions to strengthen confidence in organic products, especially imported products.

Notably, Article 36 of Regulation (EU) 2018/848 introduces stringent requirements for certifying smallholder groups. Previously, large importers could take care of the certification process on behalf of smallholder groups, but now, groups need to form a separate legal entity, install an own Internal Control System and assume all the cost and administrative burdens. The regulation also contains size limits for smallholder operators. Proponents of the new rules claim, that they create fairer competition and eventually strengthen the position of producer groups in the value chain. However, others accuse the EU of neocolonialism, as the certification rules modelled after EU standards, create insurmountable hurdles for many small producers in the global south. Our study, investigates the impact of the regulation on Ghana's organic cocoa sector through semi-structured qualitative interviews with relevant stakeholder groups. Results show a nuanced picture. While creative strategies by private actors dampen the negative effects and question the idea and legitimacy of the new rules, there is the problem of a perceived uncertainty about concrete implementation. We finish by making some concrete proposals on how EU rules could better match the situation and adequately reflect the EU's relevance and responsibility.

Keywords: Certification, neocolonialism, organic farming, regulations

Contact Address: Ohemaa Agbolosoo-Mensah, University of Bayreuth, Fac. of Life Sciences: Food, Nutrition and Health, Fritz-Hornschuch-Straße 13, 95326 Kulmbach, Germany, e-mail: mensah.oa@gmail.com

A systematic literature review on the relationships between land tenure, cattle farming, and climate change

Manuel Díaz¹, Leonardo Moreno Lerma², Natalia Triana-Angel¹, Stefan Burkart¹

¹*The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia* ²*Independent Consultant, Colombia*

Climate change is a pressing global issue with profound environmental, economic, and social ramifications. Our research delves into the intricate relationship between land tenure, exemplified by agrarian reforms, and traditional cattle farming practices, with a focus on mitigating climate change impacts through sustainable production practices and technologies, such as silvopastoral systems. Through a systematic literature review drawing on empirical evidence from six countries in the Global South, namely Brazil, Mexico, Colombia, Kenya, Nigeria, and South Africa, we shed light on the complex interplay of factors driving climate change in these regions. Our findings underscore that while agrarian reforms have been instrumental in certain aspects, such as land redistribution, they have also contributed to deforestation without yielding desired outcomes such as improved access to credit for adopting sustainable practices. Additionally, the implementation of silvopastoral systems, aimed at mitigating impacts from traditional cattle farming, faces common challenges including a lack of technical support and financial resources. These challenges impede progress in mitigating the adverse effects of traditional cattle farming, notably deforestation and greenhouse gas emissions. By adopting a historical perspective, we gain insights into the political responsibilities shared across the Global South in addressing climate change. While acknowledging ongoing efforts to enhance sustainability, our study underscores the imperative of addressing systemic challenges, such as inadequate state control in certain territories and mismanagement of public resources, to effectively combat climate change. This recognition is crucial for devising comprehensive strategies that can drive meaningful change and foster sustainable development in the face of climate change pressures.

Keywords: Agrarian reforms, global warming, land tenure security, silvopastoral systems, sustainable intensification

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Combating desertification through development projects in Namibia's Waterberg region – state building instead of desertification reduction

Markus Rauchecker¹, Meed Mbidzo², Lena Grieger³, Diego Menestrey Schwieger⁴

¹ISOE – Institute for Social-Ecological Research, Germany
²Namibia University of Science and Technology, Natural Resource Sciences, Namibia
³Goethe University Frankfurt, Institute of Physical Geography & Center for Interdisciplinary African Studies, Germany
⁴University of Cologne, Germany

Climate conditions and various socio-economic and structural factors have led to rangeland degradation in different parts of Namibia, especially in the communal areas. Here, a large part of the population depend on subsistence livestock farming to make a living. Against this background, five different development projects to combat desertification were implemented successively from 1991 until 2018 in the communal farming areas of the Waterberg region, mainly under the umbrella of the United Nations Convention to Combat Desertification (UNCCD): 1) Sustainable Animal and Range Development Programme (SARDEP), 2) Namibia's Programme to Combat Desertification (NAPCOD), 3) Desert Margins Programme (DMP), 4) Country Pilot Partnership Programme for Integrated Sustainable Land Management (CPP-ISLM), 5) Land Degradation Neutrality Pilot Project (LDN). These development projects are important platforms to bring into dialogue international treaties (UNCCD), international cooperation and UN agencies, Namibian ministries, extension services, consulting firms, NGOs and local communal farmers. Nevertheless, despite these numerous initiatives to combat desertification, desertification is still looming in the region. The overall research question is to what extent the development projects had an impact on rangeland management to reduce desertification. We analyse project reports, interviews with key informants from the mentioned projects and with farmers who experienced and participated in the development projects. We focus on, firstly, the projects' conceptualisation of desertification and its causes, secondly, the projects' measures to combat desertification and their outcome, and thirdly, the impact of the project results from a farmer perspective. Preliminary results show that the direct impact on rangeland management of communal farmers was low, but the development projects made key contributions to policies regarding rangeland management and to capacity building for people working in state entities, NGOs and consulting firms nowadays. State building and the development of the NGO sector were needed after Namibian independence in 1990.

Keywords: Communal areas, policies, rangeland degradation

Contact Address: Markus Rauchecker, ISOE – Institute for Social-Ecological Research, Frankfurt am main, Germany, e-mail: markus.rauchecker@isoe.de

Impact of foreign direct investment on environmental sustainability: Evidence from South Africa

Clarietta Chagwiza¹, Nyankomo Marwa², Farai Kapfudzaruwa¹

¹University of Pretoria, Future Africa, South Africa ²Stellenbosch Business School, Development Finance, South Africa

Countries are under pressure to meet goals such as the United Nations (UN) 2030 Agenda for the sustainable development goals (SDGs) and the African Union's Agenda 2063. As a result, developing countries, particularly in Africa, make considerable efforts to bring in more foreign direct investment (FDI) to stimulate economic growth, which in turn influences the interlinked goals and targets. However, ample evidence exists that shows that in as much as FDI is critical in promoting economic growth, it can have negative (environmental) impacts on the host economies. African countries, including South Africa, are well-endowed with natural resources and cheap labour that makes them targets for foreign and transnational investors. This, however, may lead to resource depletion posing huge negative implications on the economies. Environmental degradation implications are massive for Africa since the continent's wealth is heavily reliant on natural resources and its conservation. This paper uses time series data spanning 1971–2016 to investigate the impact of foreign direct investment (FDI) on environmental sustainability in South Africa. Two proxies of environmental sustainability are used: carbon dioxide (CO_2) emissions and natural resource depletion (NRD). The autoregressive distributed lag (ARDL) was employed for analysis. The Augmented Dickey–Fuller confirmed a mixed nature of integration of the series, i.e. I(0) and I(1) among the variables. The bounds testing results revealed that cointegration exists among the variables when NRD is the dependent variable. No cointegration existed among the variables with CO_2 as the dependent variable. With NRD as a dependent variable, the ARDL results revealed that in the long run, FDI and domestic investment negatively impacted on the environment. In the short run, FDI was found to also contribute to environmental degradation. When CO_2 was used as the dependent variable, it was found that FDI significantly promotes environmental sustainability, while GDP led to higher CO_2 emissions. The findings of this study can potentially inform policy on the importance of ensuring that the country accrues optimal benefits from FDI inflows while ensuring environmental sustainability for future generations.

Keywords: ARDL, environmental degradation, foreign direct investment, impact

Contact Address: Clarietta Chagwiza, University of Pretoria, Future Africa, Research commons 2-10. experimental farm south street, 0083 Pretoria, South Africa, e-mail: cchags@gmail.com

The role of meso-institutions in technical assistance public policies: Evidence from urban and peri-urban farms in the largest Latin American metropolitan area

Eliana Lins Morandi¹, Paula Sarita Bigio Schnaider Nissimoff², Wiltrud Terlau³

¹University of Bonn, Center for Development Research (ZEF), Germany

²School of Economics, Business and Accounting of the University of São Paulo, Brazil

³University of Applied Sciences Bonn-Rhein-Sieg, International Centre for Sustainable

Development (IZNE), Germany

São Paulo is the largest Latin American metropolitan area with 22 million inhabitants. The rapid expansion of the urban sprawl imposes challenges for mega-cities around the world and São Paulo is no exception. Supplying healthy and safe food for an increasing urban population is an important one. In this regard, policies of technical assistance and rural extension are an important tool to foster and strengthen food production. The current Brazilian policy of technical assistance (Política Nacional de Assistência Técnica e Extensão Rural - PNATER) was put into place in the early 2000s. It has set national directives to be followed by subnational governments in charge of its implementation. These are characterised as meso-institutions, i.e. the intermediate level mediating the macro-institutional level (e.g. general rules) and the microinstitutional level, in which the rules are followed or executed. PNATER services are free of charge and target specific groups, such as family farmers. The policy is also in line with agroecological principles, such as social participation. However, there is a huge heterogeneity among subnational entities providing the services. For instance, the São Paulo municipal government, with the largest municipal budget of the country, delivers its own service and has been internationally awarded by the Bloomberg's Mayors Challenge 2016. Meanwhile, other municipalities within the same metropolitan area struggle due to the lack of resources or political relevance of urban agriculture in the public agenda. In this research, three municipalities within the São Paulo metropolitan area are compared in an in-depth multiple case study: Embu-Guaçu (peri-urban agriculture), Diadema (intra-urban agriculture) and São Paulo capital municipality (peri-urban in its Southern Zone and intra-urban in its Eastern Zone) in order to analyse the role of the meso-institutions responsible for the technical assistance and rural extension public policies in those areas. We investigate whether they make a difference in the policy results and how. We conclude the paper with a broader discussion on the consequences of the current structure of PNATER and other urban agriculture supporting policies in the fostering of sustainable and fair urban planning considering the institutional heterogeneity throughout the country.

Keywords: Meso-institutions, policy implementation, technical assistance, rural extension, urban agriculture

Contact Address: Eliana Lins Morandi, University of Bonn, Center for Development Research (ZEF), Genscherallee 3 (ZEF C - OneHealth), 53113 Bonn, Germany, e-mail: elinsmor@uni-bonn.de

Ideas and legacies underlaying land-use dynamics of agricultural frontiers in the Peruvian Amazon

Miguel Angel La Rosa Salazar

Humboldt-Universität zu Berlin, Agricultural and Food Policy Group, Germany

Agriculture is crucial for the economy of the Peruvian Amazon. It contributes significantly to domestic consumption and international trade, and efforts to fight poverty rely heavily on it. Sadly, agriculture is also strongly linked with deforestation since it has expanded at the expense of biodiverse Amazon forests. Such a concerning link sets a crucial challenge for conservation endeavours to increase their effectiveness. Addressing this challenge requires understanding what fuels deforestation from its linked sides. Identifying the diverse perspectives influencing land-use dynamics of agricultural frontiers in the Peruvian Amazon is a step toward such an understanding. Based on institutionalist theories, this work portrays an overview of these diverse perspectives, how they gained relevance, and how they come together to influence the Amazon region of Peru. The analysis considers results from a literature review and expert interviews occurring now. This overview is part of a PhD research and considers national- and international-level institutions to provide a basis for a future research phase focusing on the local level. Preliminary findings reveal several sides of the agriculture-deforestation link: national and regional governments, political groups, agricultural industries and traders, farmers associations, NGOs, international cooperation, indigenous communities, drug traffickers, and religious groups, among others. Moreover, profound institutional, political, and social changes and events have affected the Amazon over the last century: The Marginal Highway, Velasco's Agrarian Reform, the internal armed conflict, Fujimori's neoliberal structural adjustment, and the first forest law undergoing prior consultation, among others. Ideas that stand out from the preliminary results are those related to economic development, modernisation, and poverty alleviation, as well as those associated with the need to conserve forests and protect indigenous territorial rights. The presentation will provide initial reflections on these results to open discussions.

Keywords: Agricultural frontiers, ideas, institutions, Peruvian Amazon

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

The imperative of policy research for scaling improved forages in the tropics

Stefan Burkart, Danny Fernando Sandoval

The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

Improved tropical forages hold significant promise in addressing the pressing challenges of food security, livestock production, and agricultural sustainability in the tropics. As global demand for animal products increases, particularly in developing countries, the adoption of these technologies presents a viable pathway to enhance livestock productivity, combat land degradation, mitigate climate change, increase resilience, and improve rural livelihoods. However, realising the full potential of tropical forages requires a comprehensive understanding of the complex interplay between ecological, socio-economic, and policy factors. This research provides a perspective on the critical role of policy research in facilitating the widespread adoption and scaling of tropical forages. Firstly, effective policies are essential for creating an enabling environment that incentivizes farmers to integrate these forages into their production systems. This involves addressing regulatory barriers, providing financial support, and promoting knowledge dissemination through extension services. Moreover, policy interventions can foster innovation in forage breeding, agronomy, seed systems, and value chain development, thereby enhancing the resilience and adaptability of farming systems to climate change and other external pressures. Furthermore, policy research plays a pivotal role in addressing the multifaceted challenges associated with forage adoption, including land tenure issues, access to inputs, market dynamics, and socio-cultural preferences. By engaging with stakeholders across the value chain, policymakers can devise context-specific strategies that promote equitable access to forage resources and ensure the inclusion of marginalised groups, such as smallholder farmers and pastoral communities. Importantly, policy research serves as a mechanism for evidence-based decision-making, helping policymakers navigate trade-offs and prioritise interventions that maximise societal benefits while minimising trade-offs. By integrating interdisciplinary approaches and leveraging participatory methodologies, policymakers can harness local knowledge and expertise to co-design inclusive policies that reflect the diverse needs and aspirations of stakeholders. In conclusion, policy research constitutes an anchor in unlocking the transformative potential of tropical forages in sustainable agriculture and rural development. By fostering an enabling policy environment that promotes innovation, equity, and resilience, policymakers can catalyze the widespread adoption of tropical forages, thereby advancing the goals of food security, poverty alleviation, and environmental stewardship in tropical regions.

Keywords: Adaptation, agricultural policy, improved forages, mitigation, scaling, sustainability, technology adoption

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Digital transformation of smallholder agriculture: Enrolment of smallholder farmers into global production and marketing paradigms

Farai Alice ${\rm Gwelo}^1,$ Naude ${\rm Malan}^2,$ Suzall ${\rm Timm}^1$

¹University of Johannesburg, Anthropology and Development Studies, South Africa ²University of Johannesburg, Dept. of Business Management, South Africa

In South Africa smallholder agriculture has historically been neglected in favour of largescale agriculture, hence, smallholder farmers (SHFs), face challenges of inequality, limited access to information, lucrative markets, financial services, land, and other productive resources. South Africa is increasing focus on digitalisation to drive transformation to address the diverse challenges faced by SHFs. Mobile apps are the most accessible digital technology and are believed to hold many benefits for SHFs. However, based on evidence from past agricultural transformations that were ill-fitted and failed to benefit SHFs in Africa there are growing concerns that digitalisation will only benefit the larger, better resourced entities, extending their control and dominance over SHFs, and thereby diminishing smallholders' ability to make autonomous decisions regarding their farming paradigms. To contribute to this body of knowledge, this research critically examined the ways in which mobile apps are transforming agriculture for SHFs in South Africa. The multiple case study methodology guided by the critical theory of technology and self-determination theory was used. Four mobile apps and forty-two SHFs using the apps were purposively selected. The research found that proprietary mobile apps undermine the autonomy and competence of SHFs by enrolling them into global production and marketing paradigms, which demand skills and resources they often lack. This enrolment, despite the clear mismatch between these paradigms and the capabilities of smallholders, and in the absence of a conducive external environment, highlights a disregard for SHFs to benefit from digitalisation and from the new farming paradigms. Hence this study puts forward that to truly empower SHFs, there must be a fundamental shift in digitalisation efforts, prioritising their interests by either empowering them to succeed within these new systems or supporting them within their existing contexts, rather than subjecting them to systems where they lack adequate resources and must compete on unequal footing with larger, more powerful actors. The findings provide key insights for informing smallholder agriculture digitalisation policy and practice.

Keywords: Farming paradigms, mobile apps, transformation

Contact Address: Farai Alice Gwelo, University of Johannesburg, Anthropology and Development Studies, Kingsway Campus, 2006 Auckland Park, South Africa, e-mail: faraigwelo@gmail.com

Transformation of the Ghanaian cocoa system: A multilevel perspective

ANINWAA BOAKYE-DANKWA, REINHARDT TILMAN University of Bayreuth, Fac. of Life Sciences: Food, Nutrition and Health, Germany

The revamp of the cocoa system in Ghana represents a multi-faceted effort to increase yield, improve farmer incomes, improve living standards and sustainability in the cocoa sector. This study uses the multi-level perspective to delve into the intricate dynamics of Ghana's cocoa sector and identify realistic strategies for development. The study looks at the effects of child labour, climate change, and unstable cocoa prices globally at the landscape level. These factors all present serious risks to Ghanaian cocoa farmers' ability to make a decent living. The Ghana Cocoa Board (COCOBOD), which has historically controlled cocoa pricing and marketing, is the main subject of the regime level research. New changes have made it possible for licensed buying companies to purchase cocoa directly from farmers. By exploration of the local niche level, geographical indication was identified by the study as a means of obtaining more value from Ghanaian cocoa. However, issues still exist, such as logistical obstacles faced by local chocolate producers and ethnocentric attitudes regarding locally made chocolate. These barriers, which include unstable power supplies and expensive imported processing equipment, drive up production costs and reduce market competitiveness. The results suggest that a transformation in Ghana's cocoa requires a multi-faceted strategy. Important propositions include increased stakeholder collaboration to negotiate more equitable farm-gate prices, regulatory interventions to support quality distinction, sustainability, and infrastructure improvements to support dependable power supply and access to processing equipment. In addition to being essential for boosting domestic demand and consumption, addressing the deeply ingrained ethnocentrism towards locally produced chocolate can also help to foster an atmosphere that is favourable for domestic cocoa processing. This research offers a thorough road map for improving the productivity, earnings, and long-term sustainability of Ghana's cocoa sector-which continues to be an essential part of the nation's agricultural economy and a vital source of income for millions of smallholder farmers-by addressing the intricate issues facing the industry.

Keywords: Child labour, chocolate production, cocoa farming, ethnocentrism, geographical indication, infrastructure, multi-level perspective

Contact Address: Aninwaa Boakye-Dankwa, University of Bayreuth, Fac. of Life Sciences: Food, Nutrition and Health, Bayreuth, Germany, e-mail: boadanani@gmail.com

Multidimensional effects of migration on output of farming households in southwest Nigeria

SARAH ENIOLA, TEMITAYO ADEYEMO University of Ibadan, Dept. of Agricultural Economics, Nigeria

The effects of migration have often been limited to the receipt of monetary remittances to sending households. However, there are other dimensions of migration with effects on the households. We argue that migration remittances could have monetary, social, and technical dimensions with differential effects on farming households' livelihood outcomes. This study investigated the multidimensional effects of migration on 115 migrant- sending and agricultural based households' production output in Saki west Local Government Area, Oyo State in Southwest Nigeria. The main reasons for migration of household members were employment, education, and farming. Destination of the migrants were mainly to other rural communities (42%); followed by urban cities (37%) and others. Social remittances included access to markets (41.4%), access to information about health (28.6%); membership of social groups (23.2%) and information about insurance (6.8%). Technical remittances on the other hand included improved access to production inputs (herbicide, pesticides), knowledge of improved practices, improved technologies and value addition. Financial remittances averaged, Naira 8,400 per month; and were mainly used for non- agricultural purposes. Thus, while financial remittance increased household income, its effect was to increase expenditure; rather than investment. Our findings further showed that among other variables, households who received social and technical remittances had significantly higher production output than those who did not; while financial remittances had reducing effect on output. Other factors that influenced production output were farm size and education. The findings bring to the fore the importance of social networks in introducing production enhancing practices among migrant sending agricultural based households. Also, policies that enhance acquiring farmland; and stronger land tenure system, while fostering community initiatives for growth are recommended.

Keywords: Agricultural production, financial remittances, migration, social remittances, technical remittances

Contact Address: Temitayo Adeyemo, University of Ibadan, Dept. of Agricultural Economics, Ibadan, Nigeria, e-mail: adeyemotemitayo@gmail.com

Urban expansion and its impact on sustainable food production: A case study of Dodowa, Ghana

Belinda Naa Saakor Djabeng, Gyula Nagy, József Lennert University of Szeged, Dept. of Economic and Social Geography, Hungary

Urban expansion is causing competition between built infrastructure and sustainable food production in Dodowa, where farmland is being lost to urban development. This expansion is occurring because of the growth of Accra, the capital city, which is causing cities to expand beyond their intended limits and encroach on once-agricultural communities. To better understand the impact of urban expansion and infrastructure on agriculture and food production, this study was conducted. The study used a quantitative approach which involved administering questionnaires to 100 households within Dodowa, a township in Ghana. Additionally, GIS and remote sensing techniques were used to analyse Landsat images of 2002, 2015 and 2024, while SPSS and Excel were used to analyse the quantitative data. The study also utilised change detection analysis of satellite images to identify land use and cover changes over a period of 22 years. The study revealed an increase in built up infrastructure and a sharp decline in vegetation suggesting urban sprawl. It was recorded that within the 22 years span data evaluated, there was a 40% increase in built up infrastructure while there was a 28% and 11% decrease in sparse and dense vegetation, respectively. The study concludes that, the loss of agricultural lands due to urban expansion is causing a decline in food production and livelihoods. To address this issue, the study recommends a collaborative effort between traditional land tenure systems and government planning agencies. This would promote sustainable land management practices and ensure proper zoning for land use areas, preserving the environment's biodiversity.

Keywords: Agriculture, built infrastructure, livelihoods, sustainable food production, urban expansion

Contact Address: Belinda Naa Saakor Djabeng, University of Szeged, Dept. of Economic and Social Geography, Budapesti Street 7, 6728 Szeged, Hungary, e-mail: belindadjabeng@gmail.com

An analysis of challenges and opportunities for upscaling the organic fertiliser industry in Kenya

Xinran Wang¹, Goetz Uckert², Kilian Blumenthal³, Sten Schurer³, Aggrey Nyende⁴, Stefan Sieber²

¹Leuphana University Lüneburg, Research Group Governance, Participation and Sustainability, Germany

²Leibniz Centre for Agric. Landscape Research (ZALF), Germany

³Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Germany

⁴Jomo Kenyatta University of Agriculture and Technology, Dept. of Horticulture and Food Safety, Kenya

Organic fertilisers are considered a feasible solution to restore low-quality soil, reduce risk to food security and improve smallholder livelihood. Their development also contributes to creating a circular economy and achieving the low-carbon and Sustainable Development Goals (SDGs) commitment of the Kenvan government. Nevertheless, the development of the industry is regionally diverse and still limited. Also, little is known about the social acceptability of organic fertilisers among relevant stakeholders despite that understanding the range of their perceptions is a key requirement for the successful management of this industry. This study contributes to shedding light on stakeholders' attitudes toward obstacles and potential measures for improvement to the upscaling of the organic fertiliser industry in Kenya. This study conducted Q-methodology to explore the perceptions of five key stakeholder groups (policymakers, farmers, private entrepreneurs, NGOs, and researchers) towards organic fertilisers in Central Kenya. Eighteen participants were invited to rank 38 statements that described 9 categories of possible challenges for the development of organic fertiliser, on a scale from 'most like I think' to 'least like I think'. The ranking results were factor analysed and interpreted in three distinct factors, where each represented a perception. Overall, all perceptions believed in the potential of the organic fertiliser market in Kenya, yet they all acknowledged numerous challenges hindering the scaling up of this industry. Perception 1 regarded the financial support, policy & legal frameworks as well as marketing strategies as the main constraints, represented by respondents mainly from the farmer group. Perception 2, by contrast, gave high importance to access to organic products and outreach strategies while perception 3 focused mainly on the lack of available scientific data on the environmental and economic efficacy of organic fertilisers. These two perceptions both comprised respondents from distinct stakeholder groups

Contact Address: Xinran Wang, Leuphana University Lüneburg, Research Group Governance, Participation and Sustainability, Universitätsallee 1 c11.131, 21337 Lüneburg, Germany, e-mail: xinran.wang@leuphana.de

who worked with farmers, whereas the stakeholder composition of Perception 3 was more diverse. As for the measures for improvement, outreach strategies and approaches concerning business dynamics, access to products, market creation and marketing strategies were highly recommended for alleviating key barriers to the development of the organic fertiliser sector in Kenya.

Keywords: Commercialized organic fertilisers, Kenya, measures for improvement, Q-methodology, self-produced organic fertilisers

Comparative study on rural and urban multidimensional poverty in conflict-stricken East Wollega zone, Ethiopia

Admassu Tesso Huluka

Ethiopian Civil Service University, Development Mangement, Ethiopia

This study investigates the dynamics of rural and urban multidimensional poverty in the East Wollega Zone, with a focus on understanding how conflictinduced shocks exacerbate socioeconomic disparities. Motivated by the urgent need to address poverty in a region marked by persistent internal conflict, our objective is to analyse the prevalence, determinants, and policy implications of multidimensional poverty. Conceptually, we adopt the Sustainable Livelihoods Framework (SLF) approach, consistent with Amartya Sen's capability approach to poverty study. Analytically, we utilise the Multidimensional Poverty Index (MPI) framework developed by Alkire and Foster, complemented by a mixed-methods approach. Our sample comprises 341 households, including both displaced and non-displaced populations, and employs a logit model to estimate the determinants of multidimensional poverty. We found statistically significant difference in multidimensional poverty across rural and urban dichotomy. While nearly 66 percent of the multidimensionally poor households are found in rural areas nearly 73 percent of the nonmultidimensionally poor households are located in the urban areas and the difference is significant at p < 0.001. We also found that exposure of households to multidimensional poverty varies by the effect of the internal conflict. While nearly 72 percent of the multidimensionally poor households are among the displaced families, nearly 92 percent of the non-multidimensionally poor households are among non-displaced with statistical significance of chi2 (1, N=341) = 45.8612, p < 0.00. We have also discovered that the location of residence, gender of the household head, literacy level, family size, dependency ratio, age of the household head, and occupation type significantly impact multidimensional poverty. Policy implications underscore the importance of integrated poverty reduction strategies, conflict resolution mechanisms, and gender-sensitive approaches to promote inclusive development and sustainable poverty reduction in the region. By prioritising evidencebased interventions and fostering community engagement, stakeholders can work towards improving well-being and resilience among vulnerable populations in the East Wollega Zone.

Keywords: Capability, conflict, east Wollega, multidimensional poverty, sustainable livelihood

Contact Address: Admassu Tesso Huluka, Ethiopian Civil Service University, Development Mangement, Lemi-Kura, Addis Abeba, Ethiopia, e-mail: admassutesso@gmail.com

Multiple crises: natural resources, food and livelihoods in fragile settings

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Disaster risk management policies and implementing tools in Morocco

Abdelilah Meddich¹, Salah Er-Raki Salah², Majida Lahrouni¹, Kholoud Kahime¹

¹Cadi Ayyad University Marrakech, Biology, Morocco ²Cadi Ayyad University Marrakech, Physics, Morocco

Disaster risk reduction and management (DRM) have emerged as primordial features of policy implementation, given the current trends spanning strategic developments globally, primordial to sustainability, building, and resilience reinforcement of hazard-prone regions. Disaster-related socioeconomic losses are witnessed globally and regionally. For instance, Morocco is vulnerable to the climate crisis, making it prone to disasters that cost a yearly average of \$800 million, according to the World Bank. Cases in point are the Covid-19 pandemic, recurrent drought episodes (resulting economic collapse of 3 % in 2016), and the latest earthquake that struck the Marrakech region (a devastating magnitude nearing 7 leading to significant damage, with around 2,946 deaths and \$10 billion losses). These substantial events provided valuable lessons to the local government practitioners, policymakers, and (sub-)communities, leading to rethinking and reassessing the pros and cons of their current management capacities in dealing with disasters. Hence, the present study provides a comprehensive overview of DRM, spanning both regional and local (national) levels. The analysis deals with the Sendai Framework for Disaster Risk Reduction and the 2030 Agenda for Sustainable Development as global schemes relevant to Africa and Morocco specifically. It reviews DRM-related standards, quality systems, and regulatory aspects governing the country, especially at the level of the Marrakech region in Morocco. It also mentions the historical background and current situation assessment, monitoring and evaluation of the DRM systems, impact on women and other vulnerable groups in Morocco, and associated knowledge gaps. The risk management in research laboratory environments is also underscored, stressing the significance of maintaining thorough safety. Risks attributed to pollution, water scarcity, and agricultural challenges, together with the climate crisis, were addressed. It also discusses scientific research and interesting development projects.

Keywords: Current situation, global and specific constraints, mitigation and adaptation, monitoring and evaluation, Morocco, pollution and nuisance, programmes and indicators, risk management, strategies adopted

Contact Address: Abdelilah Meddich, Cadi Ayyad University Marrakech, Biology, Semlalia bd. Moulay Abdellah, 40000 Marrakech, Morocco, e-mail: a.meddich@uca.ma

Unraveling the nexus of urbanisation, migration, and livelihoods of farm households

Pooja Kori

International Rice Research Institute, Evidence module, CGIAR GENDER Platform, India

The complex interplay between urbanisation, migration, and livelihoods is a critical aspect of contemporary socio-economic dynamics, particularly in regions experiencing rapid urban growth. Against the backdrop of urbanisation emerging as a global focal point, understanding its ramifications on the livelihoods of farm families assumes paramount importance. This study presents a comprehensive investigation into the intricate nexus of urbanisation and migration and its effects on the livelihoods of farm households in and around Bengaluru, India. Using a random sampling method, villages around Bengaluru were categorised into urban, transition, and rural gradients. A total of 260 farm households were surveyed, comprising 60 from urban areas and 100 each from transition and rural gradients. Results revealed varying migration rates across gradients, with the highest observed in rural areas (52%), followed by urban (46.67%) and transition (35%) gradients. Notably, rural-urban migration emerged as the predominant stream. In rural areas, migration was primarily driven by higher wages at destinations (41.76%) and better job opportunities (31.87%). A probit model analysis highlighted the significant factors influencing migration, including education, household size, non-farm income, and outstanding debt, while farm income exhibited a negative impact.

Furthermore, findings from the fractional probit model underscored the positive correlation between urban households and livelihood security, with urban households exhibiting greater livelihood security (0.61) compared to transition (0.55) and rural (0.52) households. Based on our study findings, policymakers should prioritise improving rural infrastructure, such as transportation, healthcare, and education, to make rural areas more attractive and reduce migration. Additionally, targeted interventions promoting skill development, access to credit, and financial literacy can empower farm households to diversify income sources and manage debt effectively. These measures can foster more inclusive and resilient rural economies, ultimately enhancing the well-being of farm households amidst urbanisation pressures. This study contributes to the understanding of urbanisation dynamics, migration patterns, and their implications on livelihoods of farm housheolds. The insights garnered can inform policy interventions aimed at fostering sustainable development and enhancing livelihood security in rapidly urbanizing areas like Bengaluru's periphery.

Keywords: Farm households, livelihoods, migration, rural-urban interface, urbanisation

Contact Address: Pooja Kori, International Rice Research Institute, Evidence module, CGIAR GENDER Platform, 340/c school st saheed nagar, 751007 Bhubaneshwar, India, e-mail: p.kori@irri.org
The role of agrifood entrepreneurs during ongoing war in Sudan: A gender perspective

Martina Cavicchioli, Monica Fisher, Sundus Alarabi, Mudar Ahmed, Ali Omer Abdalla

International Maize and Wheat Improvement Center (CIMMYT), Kenya

The conflict that broke out in Sudan in April 2023 has undermined the functioning of agrifood value chains, leading the country to a severe food crisis. These circumstances have resulted in the disruption of infrastructures, a dramatic increase in food prices, and in the scarcity of resources and led many farmers to lose their lands as a consequence of their displacement. Micro, small, and medium agrifood-enterprises (MSMEs) play a pivotal role in providing services to farmers facing both war- and climate-related challenges in Sudan. However, the ongoing war has forced most MSMEs to either reconfigure or suspend their operations. Our research explores the perspectives of entrepreneurs regarding the impact of conflict on their operations. Moreover, we shed light on the often-neglected role of women entrepreneurs in the agrifood sector - which existing scholarship reports being mostly dominated by men - and look at entrepreneurs' coping strategies through a gender lens. We present the results of a qualitative study that builds on semi-structured interviews conducted with forty business-owners (women and men), who work as input sellers and as crop or food processors in the States of Kassala and Gedaref. Our results provide a longitudinal perspective on the experiences of women and men entrepreneurs, which combines insights on their personal backgrounds and business history with their views on the war's impact on operations (client network, sourcing of material, service delivery, etc.) as well as on their personal ambitions. Drawing from the assumption that conflicts affect and, to some extent, challenge preexisting gender roles and responsibilities, our research also investigates how gender norms shape women's and men's capacities to start and maintain their business during times of crisis along with their sense of achievement. By building on entrepreneurs' perspectives, we develop recommendations that will help support agrifood entrepreneurs in sustaining local value chains and that foster women's participation and professional growth in the agrifood business sector.

Keywords: Agrifood value chains, conflict, gender norms, MSMEs, Sudan

Contact Address: Martina Cavicchioli, International Maize and Wheat Improvement Center (CIMMYT), ICRAF House, United Nations Avenue, Gigiri, P.O. Box 1041 Village Market-00621, Nairobi, Kenya, e-mail: martina.cavicchioli88@gmail.com

Is deforestation inherent to production systems? How field types contribute to understanding the forest frontier

Sarah Graf¹, Christine Bosch¹, Emmanuel Codjoe², Stephanie Domptail³, Christianah Ojo⁴, Temitope Ojo⁴, Oyakhilomen Oyinbo⁵

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

²University of Ghana, Dept. of Economics, Ghana

³Justus Liebig University Giessen, Inst. of Agric. Policy and Market Res., Germany

⁴Obafemi Awolowo University, Ife, Dept. of Agricultural Economics, Nigeria

⁵Ahmadu Bello University, Dept. of Agricultural Economics, Nigeria

West African forest frontiers experience massive forest conversion into tree crop plantations linked to dynamics of accumulation. Deforestation by African farmers is commonly framed as a trade-off between nature conservation and poverty alleviation. However, few studies have actually assessed the mechanisms driving deforestation processes on site. We use qualitative data collected during nine months of fieldwork in two case study villages in Ghana and Nigeria, one of which experienced ongoing deforestation. We assess how farming practices and class relations regarding different "field types" drive deforestation dynamics. A Field Type is characterised by a mix of crops, cropping method, and successive stages of plantation development. Using a political economy approach, we expand this existing concept to include social and institutional relations at field level.

Each study village is characterised by specific tenure and labour relations for each stage of the field types. Common roles in these relations are landlords, tenant farmers and farm labourers. We identify three mechanisms through which the inner logic of Field Types directly fuels forest conversion.

(i.) Food crops: In the Ghanian village, maize, cassava and plantain are interplanted between young cocoa trees. Once the tree canopy closes, farmers seek new land to interplant food crops.

(ii.) Tenure relations: Planting cocoa or oil palm trees in a plot ensures secure land rights. Additionally, landowners enforce tree planting to maximise land rent.

(iii.) Reinvestment: Farmers continuously seek to expand their holding of cocoa and oil palm. After tree planting on one plot is finished, farmers reinvest the freed up capital and labour plus the proceeds from tree crops into tenancy agreements for additional plots and wages to plant new tree crops.

Our research challenges two myths about forest loss: Firstly, while deforestation by African farmers is commonly framed as poverty-driven, deforestation

Contact Address: Sarah Graf, University of Hohenheim, Inst. of Agricultural Policy and Markets, Schwerzstr. 46, 70599 Stuttgart, Germany, e-mail: sarah.graf@uni-hohenheim.de

drivers on system level are rather linked to accumulation. Secondly, while agricultural expansion and intensification are commonly presented as substitutes; intensification does not halt the drivers identified in our study. Instead of perpetuating such myths, initiatives to stop deforestation should acknowledge and intervene in system-immanent mechanisms.

Keywords: Agroforestry, farming systems, institutional and economic structures

Gendered and intersectional access to social protection: Evidence from cattle-rearing women in Gujarat, India

Sanjana Rajasekar¹, Katja Bender², Tina Beuchelt³

- ¹University of Bonn, Center for Development Research (ZEF), One Health Graduate School, Germany
- ²University of Applied Sciences, Bonn-Rhein-Sieg (HBRS), International Center for Sustainable Development (IZNE), Germany
- ³University of Bonn, Center for Development Research (ZEF), Ecology and Natural Resources Management, Germany

Access to social protection is crucial for enhancing the resilience of vulnerable households to food insecurity. This research examines the experiences of women in cattlerearing households in Gujarat, India, as they navigated multiple intersecting crises during the COVID-19 pandemic. These challenges included income instability, health shocks, and illnesses affecting their primary source of income – cattle. The study focuses on the intersectional barriers these women faced in accessing social protection measures during this period. Qualitative data from 29 semi-structured interviews with community health workers, dairy cooperative heads, and local shop workers, five key informant interviews, and one focus group discussion with nine women from the Pethapur Mahila Dudh Mandali, along with quantitative data from a structured survey of 445 women from small-holder cattle-rearing households, was analysed. The findings suggest that due to social distancing regulations, WhatsApp groups became popular platforms to disseminate information. However, these groups systematically excluded illiterate women and women from marginalised castes, who often did not have access to mobile phones. Even in cases where information was disseminated door-to-door by community health workers, they excluded marginalised caste women, citing geographical barriers, thereby reproducing existing intersectional inequities. The study also explores the challenges faced by daughters-in-law. Post-marriage surname changes created bureaucratic and institutional barriers to accessing food security schemes, as their new identity often remains undocumented. This results in a unique challenge: they face social stigma when accessing benefits from their parental home and documentation barriers in their marital household. Consequently, their inability to avail of food security schemes reduces the household's total food supply. In patriarchal settings, where daughters-in-law typically eat last, this often means they are left with insufficient food, impeding their resilience to food insecurity in times of crisis. This study highlights the critical need for inclusive social protection design to ensure equitable access to food security for all, especially during crises.

Keywords: Food security, gender, Gujarat, India, intersectionality, social protection

Contact Address: Sanjana Rajasekar, University of Bonn, Center for Development Research (ZEF), One Health Graduate School, Genscherallee 3, 53113 Bonn, Germany, e-mail: s.rajasekar@uni-bonn.de

Assessing navigating currency fluctuations on sustainable agricultural trade balance: Insights from Iran's economic sanctions

Mojtaba Nikzad, Eva Gerharz

Hochschule Fulda (Fulda University of Applied Sciences), Dept. of Social and Cultural Sciences, Germany

The agricultural sector is always mentioned as the axis of economic growth and development, and with the expansion of the scope of trade in this sector, the exchange rate acts as a bridge between different sectors of the economy, and its fluctuations affect other economic variables of countries. On the other hand, Economic sanctions have long been considered a common and peaceful tool in the interaction between governments, so since the 90s, economic sanctions have become a common political confrontation between countries and a tool to achieve goals and promote foreign political interests. Therefore, in this study, the effect of currency Fluctuations on the trade balance of the agricultural sector was investigated, emphasising the economic sanctions of Iran from 1980 to 2022. After determining the factors affecting the trade balance in the form of the gravity model, the exchange rate fluctuations were calculated through the asymmetric generalised conditional variance model (TGARCH), and the effectiveness of each of the variables affecting the trade balance was investigated in the form of the vector error correction model (VECM). The results of the long-term relationship show that the coefficient of the exchange rate uncertainty index is negative and statistically significant. Therefore, the increase in the fluctuation of the exchange rate causes the deterioration of the trade balance of the agricultural sector of Iran. The results related to the virtual variable of Iran's economic sanctions showed that the existence of these sanctions causes the deterioration of the agricultural trade balance. Consequently, the study underscores the necessity of formulating tailored Stabilisation and support policies for the agricultural sector and strategies to mitigate currency uncertainties in agricultural trade. By deepening our understanding of these dynamics, it becomes feasible to implement measures aimed at controlling and reducing currency uncertainties more effectively. Through rigorous inquiry into these areas, policymakers and stakeholders can develop targeted interventions to bolster the resilience of the agricultural sector amidst fluctuating currency landscapes. This, in turn, contributes to the broader goal of fostering sustainable economic development and bolstering the resilience of agricultural trade in Iran and beyond.

Keywords: Agricultural trade balance, currency fluctuations, economic sanctions, Iran

Contact Address: Mojtaba Nikzad, Hochschule Fulda (Fulda University of Applied Sciences), Dept. of Social and Cultural Sciences, Leipziger straße 123, 36037 Fulda, Germany, e-mail: mojtaba.nikzad@sk.hs-fulda.de

Effects of land tenure security-driven afforestation on household food security in Ghana

ABRAHAM ZAKARIA, AL-HASSAN SEIDU University for Development Studies, Food Security and Climate Change, Ghana

Economic theory suggests that land tenure security is crucial for promoting agricultural investment and productivity to reduce household vulnerability to food insecurity. Securing land tenure through formalisation and protection of land rights is essential for sustainable rural development. This can be accomplished through land reform measures like land titling programs. The connection between tenure security, investment in planting trees, and food security through food expenditure is not well explored in the existing literature. We used a multinomial endogenous switching treatment effect model and the Seemingly Unrelated Bivariate probit framework to analyse the relationship between tenure security, investment in tree planting, and food security while considering selectivity bias from both observable and unobservable factors. The analysis was based on national household data at plot level data from 2016/2017. We found that farm households have low levels of land tenure security (21%) and investment in tree planting (11%). Land tenure security is positively correlated with investment in tree planting. Additionally, land tenure security decreases households' vulnerability to food insecurity by 3.5%, while investment in tree planting reduces vulnerability by 3.7%. Tenure security and tree planting have a greater impact (4.3%) on reducing families' vulnerability to food insecurity when households possess secure land and engage in tree planting. In terms of the determinants, gender, age, mode of land acquisition, remittance, and farm capital jointly influenced land tenure security-driven afforestation among farm households. Socioeconomic factors that are found to reduce household vulnerability to food insecurity include formal education, digital technology, production credit, remittance, family size, subscription to an insurance policy, and membership in an association. Therefore, we conclude that land tenure security among farm households is not enough but it must be accompanied by investment in long-term sustainable land management practices. Thus, tenure security incentivizes investment in sustainable land management, which helps minimise household susceptibility to food insecurity. Tree investment-incentivized policies should be introduced to enhance tenure security.

Keywords: Food expenditure share, land title deed

Contact Address: Abraham Zakaria, University for Development Studies, Food Security and Climate Change, Tamale, Ghana, e-mail: zackabram@yahoo.com

Mapping social cohesion in restoration landscape in western Rwanda: Evidence from Rutsiro and Ngororero restoration sites

Valery Ndagijimana, Katharina Löhr

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

Restoration is key to sustainable development. Ecological degradation is linked to societal factors, and therefore, restoration can be challenging in practice, especially in tropical regions. However, most restoration approaches have emphasised technical knowledge, leaving behind the socioeconomic and societal outcomes of restoration. This created a disconnection between science and practice. Additionally, it resulted in conflicting views between involved actors, whereby policymakers and practitioners often feel that researchers do not understand their needs or the impact of economic limitations and stakeholder perspectives on restoration projects. Many practitioners believe that research topics are irrelevant to their work or overlook important social, political, and logistical factors. Particularly, the local community is an important category that cannot be overlooked. There is a need for transformation in the design and governance of current restoration approaches. Adopting a collaborative approach involving multiple stakeholders offers an opportunity for sustainable restoration outcomes. It is important to consider the interests of all involved actors, which is a starting point for building a strong network of shared interests. To that end, social cohesion among stakeholders presents a vital research opportunity worthy of exploring for its potential to bring and keep different actors together. We argue that the high-quality communication, collaboration, and mutual trust among the stakeholders, the more cohesive the network is, and the more likely the restoration efforts will deliver sustainable outcomes.

By using a case study, this research identifies different actors involved in restoration in Western Rwanda. It will map out the communication, collaboration, and trust among them using Net-map-based interviews and focus group discussions. Net-Map enables mapping exercises with stakeholders to create an influence network map and generate data about actors' roles, motivations, and power at the restoration site. The integrated maps showcase stakeholder locations, types, and relationships, including their respective interests. These maps also facilitate comparisons of actor networks, influence, and communication follows. Stakeholder maps and knowledge produced help assess collaboration and trust levels, improve relationships within the network, and inform future governance frameworks.

Keywords: Mapping, net map, opportunity, restoration, social cohesion

Contact Address: Valery Ndagijimana, Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Eberswalder Straße 84, 15374 Müncheberg, Germany, e-mail: valery.ndagijimana@zalf.de

The seed system landscape for improved forages in Vietnam: Threats, trends, and opportunities

Aura Bravo¹, Thanh Huyen Le Thi², Mateo Pazos Cárdenas¹, Thinh Nguyen³, Hang Thi Dao⁴, Mary Atieno⁴, Natalia Triana-Angel¹, Michael Peters⁵, Stefan Burkart¹

¹The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia
 ²National Institute of Animal Science (NIAS), Colombia
 ³International Livestock Research Institute (ILRI), Vietnam
 ⁴The Alliance of Bioversity International & CIAT, Tropical Forage Program, Vietnam
 ⁵The Alliance of Bioversity International & CIAT, Trop. Forages Program, Kenya

Cattle farming has provided several benefits to Southeast Asian societies, such as draught power, food security, meat, milk, income generation, and status. In view of the growing demand for beef in response to the region's economic development, especially in countries like Vietnam, the sustainable intensification of beef production emerges as a road map to improve communities' livelihoods from cattle raising. Multiple efforts by stakeholders have been made to introduce and disseminate innovative practices and technologies, such as improved planted forages, which focus on overcoming barriers regarding feed shortages year round and the low nutritional and productive quality of the cattle feed basket, among others. Although producers have responded to the adoption of promising materials encouragingly, scaling remains low due to limited knowledge of new materials and barriers in the supply system. Hence, this research aims at identifying business opportunities for improved planted forages to guarantee the accessibility and affordability of these technologies, mainly to smallholder women and men farmers and ethnic minorities in the remotest areas. Our contribution relies on constructing a strategy to scale technology dissemination among cattle farmers, farmers with land available to grow forages, and forage seed companies in an effort to establish a suitable environment for sustainable cattle intensification. To achieve this, our starting point is an analytical framework of a stakeholder-based seed system to conduct a market analysis in Vietnam, marking differences among three central cattle-producing regions: Northern Mountains, Central Coast, and Central Highlands. We collected primary and secondary information using the Five Forces Framework's Porter for Industry Analysis to identify entry barriers, leading competitors in the forage seed industry, buyers and alternative feeds, suppliers, and industry threats. The actors interviewed belong to the stages of seed selection and innovation, seed production, distribution and dissemination, and variety release, protection and quality control. Although data is currently being analysed, the highlights will illustrate the competitive environment of the improved forage industry in the country that the varieties currently promoted by multilateral organisations, government, and research entities face.

Keywords: Cattle farming, climate change, improved forages, seed system

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Modelling the impact of land use choices on livelihoods and food environments in peri-urban Hanoi

Hoa Bui Thi Khanh¹, Hung Pham-Van¹, Simone Kathrin Kriesemer², Thi Thu Giang Luu², Cory Whitney²

¹Vietnam University of Agriculture, Dept. of Economics, Vietnam

²University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany

Rapid urbanisation and industrialisation cause major changes in farmers' livelihoods in peri-urban areas. A part of the agricultural lands, once productive food sources for local residents, are now abandoned or underutilised. Consequently, the food environment (context in which consumers engage with the food system) also changes. In this context, farmers who remain in agriculture grapple with the decision of whether to continue maintaining agricultural production or to explore alternative income generation options. However, a food environment conducive to a sustainable diet for peri-urban and urban consumers is crucial in addressing all forms of malnutrition. Modelling approaches offer valuable insights by simulating different scenarios and assessing the potential sustainability impacts of synergies and trade-offs. These models can support farmers to make informed decisions that balance agricultural activities and other income-generating pursuits, while maximising their livelihood.

We employed a rigorous decision-making framework, integrating literature, observational data and stakeholder consultations, particularly with farmers, to construct three distinct farm-level decision scenarios for peri-urban land-owning farmers: maintaining production on the land (MAINTAIN), rent the land to other farmers (RENT), or leave the land fallow (FALLOW). We constructed an initial impact pathway diagram to visualise these scenarios, encompassing all conceivable costs, benefits, and risks associated with the project. We translated the conceptual model into a mathematical model and used Monte Carlo simulation in the R programming language to forecast benefits and trade-offs of the decision options.

Our findings indicate that MAINTAIN yields many benefits, including income from agriculture, improved health through safe food consumption, and the preservation of cultural values. RENT provides an alternative income stream but entails risks such as fluctuating rental prices. FALLOW results in a higher level of non-farm income, but the abandonment of agricultural

Contact Address: Cory Whitney, University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Auf Dem Hügel 6, 53111 Bonn, Germany, e-mail: whitney.cory@gmail.com

land also carries inherent risks, such as potential administrative fines or land reclamation by the government under the Land Law regulations.

Our results offer valuable insights into crucial aspects of land use in periurban Hanoi. Local party leaders and committees can leverage this information to bolster support for farmers by strengthening short supply chains, implementing rental systems for land, or enhancing the economic efficiency of agricultural production.

Keywords: Decision analysis, food environment, maintaining agriculture, urbanisation

Land consolidation in Kenya: An *ex-ante* evaluation of benefits, costs and risks

Hannah Kamau $^1, {\rm Cory}\ {\rm Whitney}^2, {\rm Eike}\ {\rm Luedeling}^2, {\rm Lisa}$ ${\rm Biber-Freudenberger}^1$

¹University of Bonn, Center for Development Research (ZEF), Germany

²University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Horticultural Sci., Germany

Land consolidation has been proposed by scholars and policy-makers as a means to halt land fragmentation, increase productivity, and to create youth employment in Kenya. Agricultural policies are, however, characterised by risks and uncertainties, which can reduce their efficacy and success rates. Complex socioecological interactions and data scarcity make it difficult to use standard approaches of evaluation and planning. To overcome these challenges, we use decision analysis, an interdisciplinary approach suited for data-scarce and complex environments, to support decision-making of land consolidation in Kenya. To evaluate whether land consolidation would be an effective policy measure to achieve its aims, we used experts' knowledge elicitation to build impact pathways of land consolidation intervention and considered benefits, costs, and risks that experts considered important for intervention success. Model input data, that expressed the uncertainty of all variable in the form of probability distributions, were collected from fifteen experts after subjecting them to calibration training and from literature. We then used a Monte Carlo based simulation to project outcomes and identify important and critical variables. Our model results predict that while land consolidation is likely to boost agricultural productivity, it will have negative effects on youth employment and biodiversity conservation. The intervention costs and negative externalities are also likely to exceed the overall benefits of land consolidation. Key risks included rural populace reluctance to participate in the intervention and political interference. Important uncertainties involve the impact of larger field patch sizes on changes in agrodiversity due to higher degree of mechanisation and agricultural intensity. Our findings underscore the trade-offs of land consolidation, including potential impacts on agricultural productivity, youth employment, and biodiversity conservation. By integrating decision modelling and stakeholder involvement, our research offers valuable insights into the prospective effects of land consolidation interventions for governments in their planning and prioritisation of investments for rural development.

Keywords: Agricultural policies, biodiversity conservation, decision analysis, food security, stakeholders

Contact Address: Hannah Kamau, University of Bonn, Center for Development Research (ZEF), Genscherallee 3, 53113 Bonn, Germany, e-mail: hkamau@uni-bonn.de

Cocoa farm reconversion in Ghana's cocoa regions: The influence of farm and socio-economic factors

Mitchris Chapman Kodam, Yaw Bonsu Osei-Asare, Nana Anima Mary Akrofi, Nana Okyir Baidoo, Daniel Sarpong

University of Ghana, Dept. of Agricultural Economics and Agribusiness, Ghana

West Africa grows more than 6 million hectares of cocoa trees, representing 70% of world cocoa lands. Ghana is the second largest producer of cocoa after Cote d'Ivoire with an average cocoa yield of 330–400 kg ha⁻¹, compared to Cote d'Ivoire's yield of 500–600 kg ha⁻¹. The two main cocoa regions of Ghana are the Western (Western North and South) and Ashanti regions. The declines in production volumes from 969,000 MT in 2016/2017 to 580,000 MT in the 2023/2024 cropping season in Ghana have been attributed to factors including climate change. In the Western South cocoa region, cocoa is facing a fierce competition from other perennial crops especially rubber plantations. It is also observed in this region that several cocoa farmers are converting their cocoa farms to rubber farms (conversion). In the Ashanti cocoa region however, old varieties of cocoa are being cut down for the replanting of improved varieties (reconversion). This study assesses the determinants of cocoa farm reconversion in the study regions, and was conducted in the Ellembelle and Amenfi Central districts (Western South Cocoa region), and Afigya Kwabre North district (Ashanti Cocoa region). Data is from a baseline survey of 15 cocoa communities in July 2022 of the "Cocoa for Future Project", where 400 cocoa farm households were randomly sampled. The hypotheses are that cocoa farm characteristics (variety, disease, cocoa age, etc.) and socio-economic factors (income, education, etc.) influence cocoa reconversion. The study is significant as it exposes the real threats that the cocoa sector face from diseases and non-productive old cocoa varieties amidst the concerted policy efforts to revamp the sector. Using a logistic regression model, factors that positively influence cocoa farm reconversion to high-yielding cocoa varieties are farmer based organisation (FBO) membership, land ownership status, educational level, and cocoa farm location. The study recommends stakeholders efforts to creating an enabling environment for cocoa farmers to promote cocoa replanting.

Keywords: Cocoa regions, conversion, improved cocoa varieties, old cocoa variety, perennial crops, reconversion

Contact Address: Mitchris Chapman Kodam, University of Ghana, Dept. of Agricultural Economics and Agribusiness, JB Danquah Street, Accra, Ghana, e-mail: mitchbride@yahoo.com

Positive impact of the COVID-19 pandemic in Africa: A progress towards the United Nations Sustainable Development Goals

Rachidi Aboudou¹, Jacob Afouda Yabi², Martin Paul Jr. Tabe-Ojong³, Mohamed Nasser Baco^2

¹AfricaRice, Policy, Innovation Systems, and Impact Assessment Program (PII), Côte d'Ivoire

²University of Parakou, Lab. of Analysis and Research on the Economic and Social Dynamics, Benin

³World Bank Group, United States

The COVID-19 pandemic has inflicted significant challenges worldwide, yet emerging evidence suggests that Africa has experienced positive impacts during the crisis. We examine the extant literature on the consequences of the COVID-19 pandemic in Africa. Utilizing a systematic search strategy, this study identified and synthesized findings from relevant studies published between 2020 and 2024 on the impact of the COVID-19 pandemic. A systematic review was conducted of published studies that reported a positive impact of the COVID-19 pandemic in Africa using the preferred reporting items for systematic and meta-analysis (PRISMA) protocol. This review highlights various areas where the pandemic has catalyzed positive changes, including healthcare innovation, technological advancement, economic resilience, and community solidarity. While the pandemic has predominantly been associated with negative consequences such as economic downturns, food insecurity, healthcare challenges, and social disruptions, there is growing recognition of the positive impacts it has brought about in various spheres of life across the African continent. Environmental improvements have been observed in various aspects, such as reduction in pollution levels and improvement of air quality. In addition, we observed strengthened family bonds, an increase in quality time spent together, an improvement in work-life balance, an acceleration of the adoption of online learning, an encouragement of local entrepreneurship, an acceleration of digital transformation, an increase in the use of telemedicine, an improvement in connectivity and access to information, strengthened sense of community solidarity, and increased focus on mental well-being. These positive impacts highlight the contribution of the COVID-19 pandemic to the development of SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), SDG 9 (Industry, Innovation, and Infrastructure), SDG 13 (Climate Action), and SDG 15 (Life on Land). Understanding these positive effects is crucial for policymakers and stakeholders to leverage opportunities for sustainable development and resilience in the face of future challenges in Africa and elsewhere.

Keywords: Africa, COVID-19 pandemic, economy, healthcare, positive impact, Sustainable Development Goals, technology

Contact Address: Rachidi Aboudou, AfricaRice, Policy, Innovation Systems, and Impact Assessment Program (PII), Bouake, Côte d'Ivoire, e-mail: rachidiaboudou@gmail.com

Augmenting anticipatory action and resilience in fragile, data-challenged, conflict-affected settings: The case of Tigray, Ethiopia

MITCHELL McTough¹, Zenawi Woldeyohannes², Ross Wood³

¹International Water Management Institute (IWMI), Water, Climate Change and Resilience, Sri Lanka ²Mekelle University, Dept. of Psychology, Ethiopia

³USAID, United States

The conflict in the Tigray region of Ethiopia, which began on November 4, 2020, with a series of localised skirmishes, rapidly devolved into a devastating civil war involving multiple actors, including regional militias, the national government, and foreign troops. The conflict resulted in widespread human rights abuses and a dire humanitarian crisis that displaced millions of people. While a lack of reliable data collection in the region over the last four years makes substantiating the extent of the human toll difficult, analyst modelling suggests that the conflict may have caused 400,000–850,000 fatalities, encompassing both combatants and civilians. This study explores the compounded impacts of this poly-crisis on climate change adaptation and resilience within affected communities, particularly in urban areas hosting internally displaced persons (IDPs) where identifying sources of information that are considered trustworthy by various stakeholders and decision-makers has proven challenging.

Before the conflict, Tigray had been advancing in terms of water and infrastructure development, but the war dramatically reversed these gains, precipitating the failure of essential services and necessitating urgent humanitarian intervention. The study highlights a strategic pivot in humanitarian action praxis, moving from a traditional, unconditional no regretsäpproach towards a more conflict-sensitive and evidence-driven anticipatory action (AA) strategy in the context of conflict-induced crises.

Normative consultations in the donor community reveal an increasing demand for cross-checking needs-based data. Consequently, this study will showcase robust, evidence-driven strategies for AA, including vulnerability analysis of IDP hosting communities through a case study design, enhanced by innovative data collection tools including citizen science and remote sensing.

Keywords: Anticipatory action, citizen science, climate adaptation

Contact Address: Mitchell McTough, International Water Management Institute (IWMI), Water, Climate Change and Resilience, 127 Sunil Mawatha Colombo, 10120 Battaramulla, Sri Lanka, e-mail: m.mctough@cgiar.org

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The effect of agricultural cooperative membership on women's empowerment in the Ashanti region of Ghana

JANA MAZANCOVÁ¹, BERNICE ADU-BOAHEN¹, DADSON AWUNYO-VITOR² ¹Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences / Dept. of Sustainable Technologies, Czech Republic

²*Kwame Nkrumah University of Science and Technology, Dept. of Agricultural Economics, Agribusiness and Extension, Ghana*

Cooperative societies and farmer-based organisations are increasingly gaining popularity among farmers due to their promising potential for capacity development and women empowerment. They are seen as an avenue to address the socio-economic needs of rural communities, especially in Sub-Saharan Africa. Empirical data indicates that increased economic and social empowerment of women has a direct and positive influence on women's decision-making power in the household and community, as well as on their ability to acquire and manage productive assets. However, gender disparities persist in the agricultural sector, hindering women's contributions despite investment programmes targeting Sustainable Development Goal 5 (SDG5), which aims to empower women and promote gender equality. The study analysed the effect of agricultural cooperative membership on women's empowerment in managing their livelihood in rural Ashanti, Ghana using the Women Empowerment in Agriculture Index (WEAI) tool. For structured questionnaire-based interviews, a convenient sampling method was employed to select 106 rural women farmers, comprising 75 cooperative members and 31 non-members. A Pearson chi-square test of association was used to test the scores from the 21 statements from the WEAI's five domains (Production, Resources, Income, Leadership, and Time). The result revealed a statistically significant relationship between agricultural cooperative membership and empowerment levels among women. The income and leadership domains exhibited the highest empowerment scores among women in cooperatives. This underscores the importance of autonomy among women in managing their resources. The study recommends awareness creation through education and training on the benefits of joining an agriculture cooperative among female farmers as cooperatives have the potential to promote gender equality and empower women in managing their livelihood and resources.

Keywords: Cooperatives, equality, gender, livelihood

Contact Address: Jana Mazancová, Czech University of Life Sciences Prague, Fac. of Tropical AgriSciences / Dept. of Sustainable Technologies, Kamycka 129, 16500 Prague, Czech Republic, e-mail: mazan@ftz.czu.cz

Emergence of female agri-food entrepreneurs in Facebook commerce: A choice modelling exercise to examine consumer preferences in Bangladesh

Shanjida Sharmin 1, Christin Schipmann-Schwarze 1, T. S $\rm Amjath-Babu^2,$ $\rm Katrin Zander^1$

¹University of Kassel, Agricultural and Food Marketing, Germany ²International Maize and Wheat Improvement Center (CIMMYT), Bangladesh

Digital technology, particularly social media, has significantly altered the business opportunity landscape for female entrepreneurs in developing countries. Social media's low entry barriers and the convenience of home-based operations have made it a viable platform for entrepreneurial endeavours. Since COVID19 pandemic period, women entrepreneurs in Bangladesh have started selling various products, including agricultural products, through Facebook, which is the most popular social media platform for e-commerce in the country. Previous research highlights convenience and time savings as primary motivators for online shopping. However, there is limited understanding of consumer attitudes towards purchasing agricultural and food products via Facebook, especially from female entrepreneurs. This study aims to explore the attributes consumers consider while buying aromatic rice from Facebook commerce and whether gender of the seller exerts any influence on their decisions. In March 2024, we conducted a standardised online survey including a choice experiment for aromatic rice sold in the Facebook commerce platform. It includes attributes such as gender of the entrepreneur, product review, rice's origin, the seller's trade license, and product price. The survey was conducted with 980 consumers from 4 cities in Bangladesh, including Dhaka, Chittagong, Rajshahi and Khulna. The data will be analysed using a mixed logit model and will help to identify the drivers of food choice. The analysis is still ongoing and expected to be completed by July 2024. Preliminary results show that product reviews, production location of the rice, trade license of the seller and price drives purchase decisions on Facebook commerce. However, results also suggest that preferences vary, with female consumers possibly favouring female entrepreneurs more than male consumers. Other factors, like general trustworthiness, might also influence purchasing decisions. The study is expected to provide valuable insights to female entrepreneurs and policy makers.

Keywords: Female entrepreneurs, Facebook commerce, consumer attitude, choice experiment

Contact Address: Shanjida Sharmin, University of Kassel, Agricultural and Food Marketing, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: sharminbau41@gmail.com

Are farmer organisations (FOs) such a big deal for agroecological innovation? An assessment of small holders FOs' innovation intermediation functioning

HASSEN OUERGHEMMI, AYMEN FRIJA

International Center for Agricultural Research in the Dry Areas (ICARDA), Social, Economic and Policy Research Team, Tunisia

Integration of productivity, resource management, and institutional innovations is crucial across different system levels. Traditional research and extension services face challenges in disseminating innovations effectively, leading to the emergence of agricultural innovation system (AIS) approach. AIS involves collaboration among various stakeholders to improve technological, managerial, and institutional aspects in agriculture. Intermediary actors play a pivotal role in facilitating innovation exchange and learning processes. In Tunisia, farmer organisations (FOs) like agricultural development groups (GDAs) and mutual companies for agricultural services (SMSAs) are key intermediaries. However, there is a lack of comprehensive assessments of FOs' innovation roles, which this study aims to address using Social Network Analvsis (SNA) method. The findings aim to shed light on FOs' effectiveness as innovation intermediaries and identify potential challenges and benefits associated with their roles in innovation processes throw the comparison of three farmers groups divided by their membership statutes to detect the effect of FO presence or absence on innovation facilitation and actor's configuration. The studied sample involves 592 farmers from Kef and Siliana governorates in northwestern Tunisia. This context is the typical small-scale agriculture in semi-arid bioclimatic stage in Tunisia, with limited access to land, a family-based system combines livestock rearing with annual crops, particularly olive growing mainly for self-consumption. The results show that farmer organisations (FOs) are playing a crucial role in facilitating collaboration and knowledge exchange among farmers and other agricultural actors. However, their effectiveness varies depending on membership status and contextual factors. While FOs contribute to reshaping sales channels and optimising access to services, they face limitations in promoting inclusivity and equitable knowledge sharing. The recommendations include strengthening FOs' social dimension, addressing trust barriers, and investing in reinforcement measures to enhance their functionality. Long-term strategies should reevaluate the effectiveness of collective action and focus on fostering a culture of shared learning and local empowerment.

Keywords: Agricultural innovation, farmer organisation, innovation intermediation, small holders, social network analysis, sustainable intensification

Contact Address: Hassen Ouerghemmi, International Center for Agricultural Research in the Dry Areas (ICARDA), Social, Economic and Policy Research Team, Av hedi karray, 2049 Tunis, Tunisia, e-mail: h.ouerghemmi@cgiar.org

Achieving the SDGs in the East African drylands: Pathways and challenges towards a social-ecological transformation

INGRID ÖBORN¹, AIDA BARGUES TOBELLA¹, JAMES DREW², YLVA NYBERG², GÖRAN BOSTEDT², AGNETA HÖRNELL³, PER KNUTSSON⁴, KRISTINA LINDVALL⁴, AHMED MOHAMOUD⁵, DENNIS MPAIRWE⁶, STEPHEN MWANGI MUREITHI⁷, CHRISTINE NORAH⁵, GERD NYBERG¹, BARBARA SCHUMANN⁸, ALICE TURINAWE⁶, TOR VÅGEN⁹, LEIGH A. WINOWIECKI⁹, EWA WREDLE¹

¹Swedish University of Agricultural Sciences (SLU), Sweden
²Gothenburg University, Sweden
³Umeå University, Sweden
⁴Gothenburg University, Global Studies, Sweden
⁵IGAD, Djibouti
⁶Makerere University, Uganda
⁷University of Nairobi, Kenya
⁸Linnaeus University, Health and Caring Sciences, Sweden
⁹The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Kenya

Drylands cover 40% of the global land area, host 2 billion people, and support 50% of the world's livestock population. In the East African drylands, pastoral and agropastoral livelihoods are prominent. Drylands Transform is a trans-disciplinary research project addressing synergies and trade-offs realising the SDGs in rangelands, focusing on SDGs 2 (zero hunger), 15 (life on land) and 16 (peace, justice and strong institutions). We work in the Karamoja cluster with field sites in West Pokot and Turkana Counties, Kenya, and Napak and Moroto Districts, Uganda.

The Land Degradation Surveillance Framework (LDSF) was used to assess soil and land health. The prevalence of soil erosion, soil-water infiltration capacity, soil organic carbon, vegetation cover, structure and species composition were measured in four 10×10 -km² sites. The results showed large spatial variation, from severely eroded landscapes with low water infiltration capacity to less degraded areas. Land cover and species diversity differed across the areas. The survey findings guide the technical interventions for rangeland restoration tested in Livestock Cafés (knowledge sharing hubs), such as halfmoons for water harvesting and reseeding of grass and legumes for hay and grazing.

A household survey (n=944) revealed dominant livelihoods to be 70 % livestock keeping (pastoralism) in Turkana; 90 % livestock and crops (agro-pastoralism) in West Pokot; 45 % livestock and crops, and 50 % crops in Napak;

Contact Address: Ingrid Öborn, Swedish University of Agricultural Sciences (SLU), Crop Production Ecology, Stockholm, Sweden, e-mail: ingrid.oborn@slu.se

and 30 % livestock and crops, and 50 % other (mining, brewing, fire wood, charcoal) in Moroto. Conflicts and other challenges contributed to livelihood changes. The health and nutrition study showed that malnutrition among mothers were common (one-third in Kenya and half in Uganda), while 50–70 % of children aged 6–59 months were healthy, 25–35 % at risk of malnutrition, and up to 15 % showed moderate or severe malnutrition.

Through stakeholder workshops at local/community and district/sub-county level, alternative future scenarios for rangeland development have been developed and discussed in relation to land governance, land tenure, land use, dryland health and human wellbeing. The scenarios called 'renewed mobile pastoralism' and 'innovative agro-pastoralism' integrate and explore options for governance, land use, rangeland management, and human well-being towards a sustainability transformation of landscapes, livestock and livelihood in the EA drylands.

Keywords: Drylands, food systems, Kenya, rangeland restoration, social-ecological systems, sustainability transformations, Uganda

Bottlenecks for a powerful and applied agricultural university education in Uganda

Peter Gerstmeier, Kateryna Tuzhyk, Ralf Schlauderer Weihenstephan-Triesdorf University of Applied Sciences, Fac. of Agriculture, Food, and Nutrition, Germany

Agricultural sector and industry in Uganda are lacking well trained and educated staff, besides a formal strong developed agricultural education and extension system. Alumni of agricultural universities have serious problems to find jobs and are seen in many cases as "unemployable". An important reason for this situation is seen in lacking practical knowledge, skills and experiences. In comparison, Germany has since 55 years an excellent vocational training system that is also combined with higher theoretical education through universities of applied sciences and other educational institutions.

The study examines the current state of practice-oriented elements in university education in Uganda and compares it with the German approach. For the analyses the B.Sc. in Agriculture of HSWT in Bavaria is compared with the one of MMU in Uganda by using first results of the Erasmus+ Project BA-SIS (Boosting Agricultural Studies In Sub-Saharan Africa). A focus is given to the university - farmers relation to provide placements including length, supervision and effectiveness of placements in agricultural study courses. In addition practical elements in the lectures.

The data base for the study is the comparison of curricula by using the BA-SIS findings, key person interviews, farm visits and the own participation at this placement process during a 6 months internship in Uganda. The used method is a descriptive analysis of the two B.Sc. courses, placement farms and structures in Uganda and Germany.

The results indicate that despite a formal functioning system with placements there is a serious lack of suitable placement farms and a deficiency in practiceoriented elements in lectures. Placements lack both a distinctive impact on students and sufficient supervision by the university. Furthermore, the collaboration between higher education institutions (HEIs) and practical farmers is minimal. To improve employability of B.Sc. in Agriculture alumni it is important to develop on one side an efficient network of placement farms to give students an insight in farm realities and needs and on the other side to develop and use practical elements in lectures in the study course itself.

Keywords: Applied sciences, linkage between farms and universities

Contact Address: Ralf Schlauderer, Weihenstephan-Triesdorf University of Applied Sciences, Fac. of Agriculture, Food, and Nutrition, Markgrafenstr. 14, 91746 Weidenbach, Germany, e-mail: ralf.schlauderer@hswt.de

A comparative analysis of organic agro-food systems in developing and developed regions: Structures and policies

Arezou Babajani¹, Senour Ahmadi²

¹University of Hohenheim, Inst. of Agricultural Policy and Markets, Germany ²University of Foggia, Economics, Italy

In response to significant concerns surrounding agro-food systems, including achieving a stable and sustainable agricultural system that balances profitability, food safety, environmental sustainability, and economic fairness, organic farming systems have been proposed. Despite challenges, policymakers, planners, and producers are urged to develop this system while considering standards and optimal benefits for both supply and demand sides. According to a report by FiBL and IFOAM, in 2022, approximately 96.4 million hectares of agricultural land globally (2.0 percent of farmland) were organic, with Oceania and Europe leading in organic land areas. The organic food market also reached nearly 135 billion euros, with the United States, European Union, and China being the largest markets. Therefore, the most significant advancements in organic agro-food systems have occurred in developed nations. To address this gap and offer suitable recommendations for policymakers and planners in developing regions, this study aims to identify the disparities in the background and conditions of organic agro-food systems between developed and developing regions using a snowball review approach. The results categorise different developmental components of organic agro-food system development into two main contexts: the bio-physical context (including climatic conditions, natural inputs, and land use patterns) and the socio-economic context (including governmental and political structures, social structures, social capital, economic matters, and underdeveloped infrastructures). The transition to organic agro-food systems involves two main approaches, each with two sub-categories: top-down (policy-driven and commercial) and bottomup (natural farming systems and consumption or demand-driven). In this regard, the choice between organic or conventional production systems in a region depends on local contexts such as governmental, demographic, and agro-environmental structures and infrastructures, as well as the priorities of different stakeholders, including policymakers, consumers, farmers, and other decision-makers across the supply chain. The findings suggest that in developing regions, attention should be paid to basic drivers to develop certified organic agro-food systems, such as legislation and inspection-body systems, financial support policies, increasing societal awareness through educational and training systems, and institutional development, including farmers' associations and infrastructures, such as market networks of organic products.

Keywords: Developing countries, organic agriculture, organic agro-food systems, policy implications

Contact Address: Arezou Babajani, University of Hohenheim, Inst. of Agricultural Policy and Markets, Stuttgart, Germany, e-mail: arezou.babajani@uni-hohenheim.de

Does participation in socially responsible business practices affect the performance of food processing enterprises: Lessons from youth-owned businesses?

Bernard Kwamena Cobbina Essel

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

The integration of Business Socially Responsible (BSR) into business operations has received increasing attention due to its potential impact on business performance and sustainability. To address both observed and unobserved bias in the study, we employed propensity score matching and endogenous treatment effect models to examine the factors influencing the participation of youth-owned food processing enterprises in socially responsible business practices. It examines the different outcomes for practising and nonpractising youth-owned food processing enterprises. Quantitative and qualitative data were collected through face-to-face interviews with 244 youthowned food processing enterprises from three regions of Ghana in 2021. The results show that most entrepreneurs (50%) are highly educated. The average age of the businesses was four years, while eight different food categories were processed. The probit regression results showed that the food processor's record keeping and business start-up motivation positively influenced Business Socially Responsible. Subsequently, social media presence had a positive effect on food processors' BSR practices. An interesting aspect of the study was comparing business performance between young food processors who participated in socially responsible business practices and those who did not. The results showed that young food processors who participated in BSR had a higher net profit than their counterparts who did not participate in BSR. This suggests a positive correlation between participation in socially responsible business practices and business performance among young food processors. The study concludes that active involvement in BSR activities improves business performance among young food processors. The study concludes that active participation in BSR activities improves the business performance of young food processors. These findings underscore the potential benefits of incorporating socially responsible practices into business operations to enhance the economic success of young entrepreneurs in the food processing industry.

Keywords: Business socially responsible, food processors, Ghana

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

Opportunities and agricultural interventions in coastal Bangladesh: Farmers' aspirations and production strategies

MD AMIRUL ISLAM¹, SHYAM PARIYAR¹, MATHIAS BECKER¹, TIMOTHY J. KRUPNIK² ¹University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES) - Plant Nutrition, Germany

²CIMMYT, Bangladesh

Despite progress in enhancing food security, persistent challenges remain in coastal regions of southern Bangladesh. Farmers' perceptions, decision-making processes, and adoption strategies for crop production under changing coastal environments directly influence their contributions to food security. Therefore, gaining insights into farmers' aims and needs is essential for developing effective agricultural interventions and support mechanisms. To address the key needs and aspirations of farmers, we developed a framework centreed on three major farmer aspirations: increasing productivity, reducing hardship, and alleviating risk through various production strategies. We conducted a diachronic analysis of production practices and yield attributes across 240 farm households, distinguishing between marginal and favourable sites in southern Bangladesh and compared between the years 2021 and 2011. Our findings revealed a significant ($p \le 0.05$) increase (more in favourable site) in the adoption of intensification practices over the study period. The majority of farmers adopted modern genotypes (87–93%), mineral fertilisers (73–80%), and pesticides (70%) to enhance productivity, resulting in significant ($p \le 0.05$) positive yield differences compared to non-adopters across all sites. Mechanisation, including tillage and threshing, also increased significantly ($p \le 0.05$), although mechanical harvesters were not adopted in favourable sites. Nearly all adopters used machines to reduce physical labour, reflecting a shift towards labor-saving technologies like organic amendments and herbicides. Dry-season rice demonstrated more substantial yield increases and higher yield variability than wet-season rice. Despite minimal changes in rice diversification, correlation analyses identified significant relationships between intensification practices and grain yield. Multiple regression analysis highlighted the primary influence of mineral nitrogen (N) fertiliser application followed by modern genotype adoption on grain yield. Furthermore, household characteristics such as family labour per hectare, education level, and farming experience significantly influenced mineral nitrogen (N)use and adoption of production strategies. In conclusion, farmers' aim to increase grain yield is mainly driven by mineral nitrogen (N) use and modern genotype adoption, with household attributes playing a key role in adoption strategy. These insights have broader implications beyond southern Bangladesh, offering valuable lessons for regions facing similar agricultural constraints and challenges.

Keywords: Diversification, grain yield, intensification, Oryza sativa, 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

Caring, learning, doing, relating- role of training on dynamic agroforestry in reshaping relational patterns in smallholder systems in Bolivia

Julia Männle¹, Johanna Rüegg², Joachim Milz³, Stefanie Lemke¹, Lorenz Probst¹

¹BOKU University, Institute of Development Research, Austria ²Research Inst. of Organic Agriculture (FiBL), International Cooperation, Switzerland ³Ecotop Foundation, Bolivia

Dynamic agroforestry is recognised as a promising alternative to unsustainable land use practices for its potential to restore ecosystems while increasing the resilience of production systems and livelihoods. The importance of training in fostering the uptake of more sustainable production methods like dynamic agroforestry is regularly emphasised but remains poorly understood. Existing research predominantly focuses on economic outcomes, often obscuring processes of learning, changes in practices, perceptions, values, attitudes, and the interrelatedness of the change process with its wider socioecological context. In the Alto Beni region in Bolivia, dynamic agroforestry has been promoted for almost two decades, conducting regular one-year training programmes. Our objective was to explore the effect of this training on former participants in a holistic manner. Drawing on relational ontologies and socioecological systems research we conceptualise socioecological systems as an intertwined, dynamic, relational web in which the training is embedded. Using this understanding as a heuristic, we identified relations to human and non-human entities within the relational web of former participants and assessed how these relations were influenced by participation in the training. Data was obtained through semi-structured interviews, narrative walks, a mapping exercise, and a discussion and reflection workshop with 21 farmers and technicians. Content analysis was done using ATLAS.ti. We identified four emerging key relational patterns: I) care and socioecological stewardship practices, II) changed relation to oneself, III) increased resilience through new ways of doing and relating, and IV) ongoing relational learning. We find that participation in training reshaped both the quantity and quality of the relations. Participants from the Alto Beni region maintained more and stronger relations with training providers and other participants beyond the training compared to those from other regions. We further find that the training has different implications for its participants, highlighting that complex processes of change need to be understood within its wider social, cultural and political context. Our results show that beyond the transfer of technical knowledge, the training strengthened social and socio-ecological relations of participants, thereby achieving a more sustained practice change. Continuous support and proximity to training providers were crucial in maintaining these changes.

Keywords: Bolivia, change processes, dynamic agroforestry, relationality

Contact Address: Julia Männle, BOKU University, Institute of Development Research, 1190 Vienna, Austria, e-mail: julia.maennle@boku.ac.at

Resource use efficiency under sustainable intensification practices among maize farmers in rural Ghana

Emmanuel Tetteh Jumpah, Miroslava Bavorová, Bernard Kwamena Cobbina Essel

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

Given the substantial investments, both public and private, in sustainable food systems, recent academic and scientific research has prioritised the examination of their impact. Notably, studies focusing on the effects of smallholder sustainable intensification have highlighted its significant contribution to livelihood enhancement. However, the question of whether smallholders employing sustainable intensification technologies (SIT) operate efficiently in production remains underexplored and subject to public debate. This study addresses this gap by analysing the impact of sustainable intensification technologies adoption on the technical efficiency of smallholder farmers in northern Ghana. Employing a multistage sampling technique, quantitative household-level data were collected from 461 households in the region, comprising 224 adopters of sustainable intensification technologies and 237 non-adopters. The mean maize output was observed at 1679.96 kg per acre for adopters and 1288.74 kg per acre for non-adopters. Adopters utilised more land (4.8 acres), labour (7 persons per acre), and capital (GHS 709.82 per acre) compared to non-adopters. Conversely, non-adopters exhibited higher usage of fertiliser (111.14 kg per acre), maize seed (40.09 per acre), herbicides (2.91 liters per acre), and pesticides (2.92 liters per acre). Both groups were found to underutilise land, although this phenomenon was more pronounced among non-adopters. Adopters displayed higher inefficiencies in labour and capital utilisation, whereas non-adopters demonstrated inefficiencies in seed and herbicides usage. Nevertheless, overall, adopters were observed to underutilise production resources, with potential for increasing resources by 0.22 (p-value = 0.03). Using the Stochastic Frontier Analysis, farmers' inefficiency was found to be influenced by various factors including geographical location, age, household size, gender, primary education, access to extension services, farm size, experience, and adoption of sustainable intensification technologies. Notably, gender, age, household size, and experience were associated with reduced technical inefficiency. The mean technical efficiencies for adopters and non-adopters were observed at 0.724 and 0.899 respectively. Although technical efficiency among adopters appeared lower initially, this is anticipated given that exposure to new farming practices typically leads to efficiency improvements over time.

Keywords: Maize, northern Ghana, smallholder, stochastic frontier analysis, sustainable intensification

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

Designing agricultural advisory to promote social equity in the diffusion of climate-smart agricultural practices: Lessons from Zambia

Monica Fisher¹, Paswel Marenya¹, Anton Eitzinger², Cleopatra Nawa Kawanga³, Cynthia Chibebe³, Brian Mpande³, Milton Malama³

¹International Maize and Wheat Improvement Center (CIMMYT), Kenya ²The Alliance of Bioversity International & CIAT, Climate Action, Colombia

³International Maize and Wheat Improvement Center (CIMMYT), Zambia

The proposed presentation will share a Zambia case study of the design and testing of mobile phone-enabled agricultural advisory (m-advisory) to reach and benefit diverse smallholder farmers with information on climate-smart agricultural (CSA) practices. In Zambia, an m-advisory service called Atubandike ("let's have a conversation" in local language, *Tonga*) provides beneficiary farmers access to a toll-free hotline using Viamo's interactive voice response (IVR), capacitates village-based digital champions to build trust in and support hotline use, and engages communities in gender transformative dialogue. Farmers registered by the project (56% women, 34% youth) call into the hotline and navigate several menu options to access static and dynamic content in local languages. Static content is a set of pre-recorded messages on CSA practices co-developed with farmers. Dynamic content is continuously developed and released weekly during project life. Farmers share their experiences and ask questions, by recording messages on their phone. Farmer recordings are then developed into "shared experiences" and "talk shows" by a content development committee with farmer, government, and scientist representation. In the process, farmers are empowered as creators of agricultural content.

The proposed presentation will begin by describing the Atubandike design journey, highlighting approaches used to promote inclusive design at different stages. We then describe the randomised control trial with five treatments (T) for evaluating variants of Atubandike: (T1) push m-advisory (static content only); (T2) m-advisory with feedback opportunities (static plus dynamic content); (T3) hybrid m-advisory (we engage village-based digital champions); (T4) hybrid m-advisory with digital champion training in inclusive communication skills; and (T5) hybrid m-advisory with gender transformative community engagement. Impacts of treatments will be assessed for the following outcomes, disaggregated by gender and age: trust in mobile phones as sources of agricultural information, participation in m-advisory, and awareness and knowledge of CSA practices. The presentation will next present baseline survey results from Zambia that elucidate farmer readiness to productively use their phones for agricultural advice, and how survey results are being used to modify the Atubandike design. We will conclude with a discussion of initial ideas for viable business models to ensure sustainability of Atubandike beyond the project life.

Keywords: Agricultural extension, digital extension tools, gender

Contact Address: Monica Fisher, International Maize and Wheat Improvement Center (CIM-MYT), Nairobi, Kenya, e-mail: m.fisher@cgiar.org

Safeguarding human and environmental rights in agricultural supply chains - A risk management toolkit

Andrés Charry¹, Jenny Wiegel¹, Pablo Siles¹, Luisa Claros¹, Thuy Thanh Nguyen², Mai Nguyen², Tiffany Talsma³

¹The Alliance of Bioversity International & CIAT, Colombia ²The Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT), Vietnam ³The Alliance of Bioversity International & CIAT, Ghana

All actors involved in a supply chain benefit from the labour and environmental conditions that allow for the production and trading of their respective products. Consequently, they are jointly responsible for the negative effects derived from their productive and commercial activities. It could be argued that the degree of responsibility should be tantamount to the magnitude of revenues.

In recent years, this conclusion has gained greater prominence. Consumers now demand that companies be held accountable for adverse practices that may occur in their supply chains, even if they are not directly involved in those activities. Consequently, companies and financial institutions are becoming more cautious and interested in mitigating the adverse environmental and social effects that their operations may promote in various territories, particularly in the global south.

In response, the Alliance of Bioversity International and CIAT in collaboration with FMO and Mercon Coffee Group developed a supply chain risk assessment and management toolkit, with the objective of helping companies assess the risks of engaging with or endorsing unlawful/unethical practices in their agricultural supply chains, and defining adequate measures to prevent, minimise and mitigate their impacts. The toolkit groups risks in three major Areas: Labor (forced and child labour), Human Rights, and Environment, and allows analysing these risks at a Macro and Micro level, providing companies a contextualized, nuanced, and granular understanding of the challenges they (may) face, and guide the development of tailored risk management strategies.

In this study, we present the results of the macro risk assessment module applied for the coffee supply chain in eight countries, which highlights potential risks at the national level, providing insights and informing the potential presence of adverse practices in these coffee supply chains.

Keywords: Child labour, environmental impact, forced labour, risk assessment, supply chain, sustainability

Contact Address: Andrés Charry, The Alliance of Bioversity International & CIAT, Km 17 recta Cali - Palmira, Cali, Colombia, e-mail: a.charry@cgiar.org

Co-developing innovations for sustainable land management in West African smallholder farming systems - COINS

Jonas Meier¹, Frank Thonfeld¹, Niklass Heiss¹, Ursula Gessner¹, Madina DIANCOUMBA², YVONNE AYARIBIL², JOHANNES SCHULER², MATHIAS HOFFMANN², HEIDI WEBBER², VALERIE GRAW³, STEFANIE STEINBACH³, NIELS DEDRING³, ANDREAS RIENOW³, ERIC TAMBO⁴, TARISAI KANEYPI⁴, HYCENTH TIM NDAH⁵, JAVIER MIRANDA⁶, THUY HUU NGUYEN⁷, AMIT KUMAR SRIVASTAVA², THOMAS GAISER⁷, SIDY TOUNKARA⁸, PAUL NDIAGA CISS⁸, LAURE TALL⁸, P. C. SIBIRY TRAORÉ⁹, JANET MUMO MUTUKU⁹, CELESTE TCHAPMI NONO NGHOTCHOUANG⁹, Khadidiatou Faye⁹, Daniel Annerose⁹, Amos Tabalia¹⁰, Lilian Waithaka¹⁰, LINDA BUSIENEI¹⁰, KWAME HACKMAN¹¹, NARCISSE YEHOUENOU¹², LEONARD Dakpo Akoba¹¹, Audrey Codija¹¹, Charles Sanou¹¹, Belko Diallo¹¹, Gifty Ampomah¹³, Denton Fatima¹³, Bright Sallah Freduah¹⁴, Dilys Sefakor Maccarthy¹⁴, Bashiru Haruna¹⁵, Alhasan Lansah Abdulai¹⁵ ¹German Aerospace Center (DLR), German Remote Sensing Data Center (DFD), Germany ²Leibniz Centre for Agric. Landscape Res. (ZALF), Germany ³*Ruhr-University Bochum, Institute of Geography, Germany* ⁴UNU-EHS, Germany ⁵University of Hohenheim, Dept. of Communication and Advisory Services in Rural Areas, Germany ⁶University of Bonn, Inst. for Food and Resource Economics (ILR), Germany ⁷University of Bonn, Inst. Crop Sci. and Res. Conserv. (INRES), Germany ⁸Initiative Prospective Agricole et Rurale (IPAR), Senegal ⁹Manobi Africa, Senegal ¹⁰ACRE Africa, Kenya ¹¹West African Science Service Center on Climate Change and Adapted Land Use (WAS-CAL), Burkina Faso ¹²West African Science Service Center on Climate Change and Adapted Land Use (WAS-CAL), Ghana ¹³UNU-INRA, Ghana ¹⁴University of Ghana, Soil and Irrigation Research Centre, Ghana ¹⁵Savanna Agricultural Research Institute (SARI), Ghana

West Africa is facing the major challenge of securing sustainable living conditions in the face of climate change, social transformation and a growing population. Efficient land management is needed to ensure long-term food security and sovereignty in Africa while at the same time conserving natural resources. One aspect of efficient land management can be the intensification of agriculture, i.e. the sustainable increase in productivity without taking up new land. In COINS, we catalogue methods of sustainable intensi-

Contact Address: Jonas Meier, German Aerospace Center (DLR), Earth Observation Center, Muenchener Strasse 20, 82234 Wessling, Germany, e-mail: jonas.meier@dlr.de

fication (SI), assess their suitability in local contexts in study areas in Ghana and Senegal and implement suitable measures on the ground. In doing so, we integrate stakeholders and actors in innovation labs in order to jointly identify mechanisms and framework conditions under which SI of agriculture can work. In addition, we strengthen the skills and knowledge of farmers and other key stakeholders so that SI can be successfully implemented. The targeted SI practices cover specific aspects of integrated soil fertility management (ISFM) in rainfed systems of Northern Ghana and the system of rice intensification (SRI) in irrigated systems of the Senegal river valley. Digital technologies play an important role throughout the project. We take a landscape approach based on modelling, earth observation and data science to promote improved cropping and agricultural management practices for SI on productive land and soil rehabilitation practices on degraded soils. By operationalizing support mechanisms, including comprehensive risk management strategies and an incentive and monitoring program, we aim to create the conditions for sustainable land management. Great importance is also attached to the development of a range of advisory services for farmers to implement the SI, so that the achievement of the goals defined by the stakeholders is supported. The results of the project will serve as a basis for local stakeholders and decision-makers, enabling the implementation of proven SI practices to enhance resilience against climate change and promote sustainable agricultural intensification. Here, we introduce the research project and present first results from both study sites.

Keywords: Agriculture, food security, Ghana, integrated soil fertility management, land management, Senegal, sustainable intensification, system of rice intensification, West Africa

Enhancing model calibration and validation through participatory engagement

 $\begin{array}{c} {\rm Priscilla\;Kephe}^1, {\rm Abel\;Chemura}^2, {\rm Siyabusa\;Mkuhlani}^3, {\rm Kingsley\;Ayisi}^4, \\ {\rm Brilliant\;Petja}^5 \end{array}$

¹Julius Kühn Institute, Institute for Strategies and Impact Assessment, Germany

²University of Twente, Fac. of Geo-Information and Earth Observation (ITC), Dept. of

Natural Resources, The Netherlands

³International Institute of Tropical Agriculture (IITA), Kenya

⁴University of Limpopo, Risk and Vulnerability Science Centre, South Africa

⁵Water Research Commission, South Africa

Crop simulation models play an important role in agricultural decision-making by providing insights into crop growth, yield potential, and responses to various management practices and environmental conditions. Enhancing the precision of models is critical for formulating informed decisions aimed at bolstering sustainability and fortifying resilience against the impacts of climate change. This is particularly so given that model effectiveness often hinges on the precision of underlying assumptions and data inputs, which may not always align with the complexities of real-world farming practices. Overcoming this challenge requires bridging the gap between theoretical models and practical realities, which can be achieved through participatory approaches. This study presents insights from participatory engagement with 600 farmers, aimed at refining crop simulation models' calibration and validation processes. Participatory approaches were used for systematic data collection on crop varieties, planting dates, water management and pest management strategies. Farm assessments and field visits provided opportunities for direct observation and validation of farming practices, while participatory rural appraisal techniques facilitated in-depth discussions and data visualisation. The survey period was between 2016–2018 across agroecological zones in Limpopo, South Africa. The Decision Support Tool for Agrotechnology Transfer (DSSAT v4.7), a dynamic crop model, was used to simulate yields of three crops: soybean, sunflower, and groundnut, based on data provided by farmers. Our calibrated model showed good agreement between reported and simulated yields with calibration efforts, resulting in an average accuracy rate of \geq 75%. Validation of the calibrated models further demonstrated their efficacy in capturing farmer's management practices. By integrating input data from farmers into model simulations, this research illuminates the transformative potential of participatory approaches within crop modelling research. By adopting inclusive methodologies and integrating farmers' experiential knowledge and localised insights into crop models, we enhance the robustness of the calibration and validation processes, leading to more reliable predictions of crop growth and yield outcomes.

Keywords: participatory approach, agricultural research, DSSAT, food security

Contact Address: Priscilla Kephe, Julius Kühn Institute, Institute for Strategies and Impact Assessment, 14532 Kleinmachnow, Germany, e-mail: priscilla.kephe@julius-kuehn.de
Women adoption of improved seeds in sorghum production: Insights from Tanzania

Thedy Kimbi¹, Elizabeth Kalema², Martha Swamila³, Essegbemon Akpo⁴, Christopher Magomba¹, Fulgence Mishili¹, Stefan Sieber⁵

¹Sokoine University of Agriculture (SUA), Dept. of Agricultural Economics and Agribusiness, Tanzania

²Farm Africa, Value chain Department, Tanzania

³*The Center for International Forestry Res. and World Agroforestry (CIFOR-ICRAF), Tanzania Country Programme, Tanzania*

⁴International Center for Agricultural Research in the Dry Areas (ICARDA), Lebanon ⁵Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

Agricultural production plays an important role in enhancing food security and livelihoods of the rural population in developing nations. With the challenge of climate change, sorghum production has emerged as a crucial aspect of agricultural sustainability offering resilience and adaptation strategies. Productivity-enhancing agricultural technologies such as resilient crop varieties, complementary inputs, improved irrigation systems, and farming equipments are necessary for advancing the Sustainable Development Goals (SDGs). Despite various initiatives, technology adoption rates among smallholder farmers, especially women, remain notably low in Tanzania. With recent efforts in empowering gender-inclusive technology utilisation, addressing gender disparities in agricultural production remains critically important. The objective of this study is to analyse the socioeconomic and institutional determinants influencing women's decisions regarding the adoption of improved seeds in sorghum production in Tanzania. Using cross-sectional data from 240 respondents, we employed a binary probit model for analysis. The descriptive results show that approximately 48% of female farmers use improved seeds for production. Additionally, findings from the binary probit model reveal that factors such as improved seed price, participatory varietal selection programs, pesticides use, and herbicides use significantly and positively influence adoption of improved sorghum seeds, while household member role, off-farm income, and production experience have a significant and negative association with women's decision towards use of improved sorghum seeds. As a result, this study suggests improving access to production inputs, implementing farmer training programs, and ensuring the availability of high-quality seeds, as these measures hold the potential to boost farmers' productivity, improve livelihoods, and promote sustainable development.

Keywords: East Africa, gender empowerment, improved seeds, poverty reduction, sorghum

Contact Address: Thedy Kimbi, Sokoine University of Agriculture (SUA), Dept. of Agricultural Economics and Agribusiness, Morogoro, Tanzania, e-mail: kimbithedy@gmail.com

Use of real-time load profile measurement to optimise photovoltaic systems dimensioning in shea butter production

Wiomou Joévin Bonzi¹, Bignon Stephanie Nounagnon², Sebastian Romuli¹, Yrébégnan Moussa Soro², Joachim Müller¹

¹University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany

²International Inst. for Water and Environmental Engineering, Lab. for Renewable Energies and Energy Efficiency, Burkina Faso

Productive use of renewable energy, particularly solar power, is essential for sustainable energy provision, especially in resource-constrained regions like sub-Saharan Africa. Accurate data on energy consumption patterns is crucial for properly sizing photovoltaic systems. However, conventional sizing methods, particularly for commercial and industrial needs often overestimate requirements, leading to economically onerous systems. Intuitive methods rely on simplified computations based on worstcase scenarios, such as lowest monthly average irradiation and daily load demand. They fail to consider solar irradiation fluctuations. Numerical methods, involve simulations at regular intervals. However, their practical application relies on interviews or electrical bills, which lacks accuracy in evaluating dynamic electrical consumption. This study tackles this challenge by developing a remote measurement system to monitor power consumption in a shea butter production facility (SOTOKACC, Toussiana, Burkina Faso). Shea, a popular product in the cosmetic, pharmaceutic, and food industries globally, originates solely from sub-Saharan Africa, where it sustains livelihoods for over 16 million rural women. While traditional methods still dominate shea butter production, initiatives aimed at adopting mechanical presses for extraction are on the rise. The system developed comprises two Arduino devices: a weather station and a power sensor. The weather station, powered by solar energy, recorded solar irradiation, ambient temperature and relative humidity. The power sensor, equipped with current clamp and voltage sensors, monitors various electrical parameters across three phases. The data were transmitted to an online platform via a Wi-Fi network. Over a two-month period, constant measurements were conducted to delineate the facility's load profile. Sizing was performed using the HOMER Pro software to determine the characteristics of the most cost-effective photovoltaic system for the facility. A comparison was made between the conventional sizing procedure based on monthly electrical consumption and that based on remote measurements. Results indicate that load profile evaluation yields more cost-effective solutions with reduced storage requirements compared to traditional methods. This research highlights the potential of affordable measurement tools in developing sustainable energy solutions for small and medium-sized enterprises (SMEs).

Keywords: Economic feasibility, plant oil, remote sensor, renewable 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

Identifying information needs among pastoral livestock keepers: Insights from scouting practices in northern Kenya

Rufo Roba Halakhe¹, Raphael Gudere², Debano Waqo², Lilli Scheiterle¹, Brigitte Kaufmann^{3,1}

¹German Institute of Tropical and Subtropical Agriculture (DITSL), Germany

²Centre for Research and Development in Drylands (CRDD), Kenya

³University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), Germany

In northern Kenya, the strategic mobility of herds allows herders to utilise grazing areas that are characterised by high temporal and spatial variability. To make grazing decisions, herders rely on site-specific data. Before moving to a new grazing area, they need to inform themselves about the current situation by visiting and inspecting the grazing area (scouting). The aim of this study is to investigate the information needs of pastoralists, focussing on their grazing management. In particular, the following research question is to be answered: What are the information needs of pastoralists during their scouting activities and how do these needs influence their decision-making processes? The analysis is based on qualitative data collected through focus group discussions and narrative interviews with the Borana and Rendille communities over a period of four months in northern Kenya. The activity and knowledge analysis approach was used to identify key themes and knowledge embedded in scouting practices. The results reveal a wide range of information needs that influence the mobility decisions of pastoralist communities. These include indicators of pasture and water availability and quality, as well as livestock health and behaviour. Concerns about safety, weather conditions and the nature of the land are among the factors that influence mobility decisions. This information is usually gathered and passed on by trusted scouts. The introduction of motorbikes and mobile phones over the last decade has helped to make this information sharing more efficient. Understanding the diversity and interplay of factors that influence grazing decisions helps to better understand pastoralists' utilisation of grazing areas. Currently, information from visual inspections is shared verbally, which can lead to the loss of important information and misunderstandings - revealing the potential of information and communications technology (ICT) with visual aids. However, ensuring the trustworthiness of the information shared remains paramount to minimise potential loss and disruption.

Keywords: Decision making, Eastern Africa, grazing itineraries, mobility

Contact Address: Rufo Roba Halakhe, German Institute of Tropical and Subtropical Agriculture (DITSL), Steinstrasse 19, 37213 Witzenhausen, Germany, e-mail: r.halakhe@ditsl.org

Using farmer-to-farmer field days to support adaptation to climate change in Ethiopia

Tigist Worku¹, Birgit Habermann², Shenkute $Goshme^3$

¹International Livestock Research Institute (ILRI), Sustainable Livestock Systems, Ethiopia

²International Livestock Research Institute (ILRI), Sustainable Livestock Systems, Kenya ³ARARI, Debre Birhan Agricultural Research Centre, Ethiopia

The concept of farmer-to-farmer field days (F2F-FDs) builds on the understanding that socially diverse farmers' epistemologies are varied yet similar. F2F-FDs are an approach that recognises co-production as important. Farmers like to learn about innovations in practical and visual ways, ideally from other farmers. Inherent in the approach is the option to reach more people through group formation and working with a snowball effect.

The farmers who are organising and facilitating the F2F-FDs are so called pioneer farmers. They were selected with an approach called Pioneer Positive Deviance (P-PD). In this approach we look for those farmers who perform better than others under the same circumstances. This means they implement adaptation practices more successfully than others and are willing to share this knowledge and practice with peer farmers.

In North Shewa Zone, Ethiopia, six F2F-FDs were held in 2021 and 2022 on sheep fattening practices with 77 participants. The facilitating four pioneer farmers and the participants were interviewed at the end of the field day about their experience. Six months later, 31 were interviewed for a follow up to understand how useful the F2F-FDs were for them. Based on the feedback, the pioneer farmers then organised a second F2F-FD.

In our research we found that the following aspects were crucial for managing F2F-FDs successfully: one is representativeness of participation to ensure social inclusion as well as gender equity. Secondly, it is crucial to manage expectations so that the objectives of the F2F-FDs are clear for all actors involved to avoid dissatisfaction. Thirdly, one of the positive effects of a F2F-FD is a change in self-perception of the facilitating farmer who realises in the process that they have something to share with others, they get confirmation that what they do is right, and are motivated to share with others. Finally, F2F-FDs helped to create more linkages to other farmers, and to extension agents, to create a knowledge network and groups to continue learning in mutual and practical ways.

Keywords: Ethiopia, field days, participation, positive deviance

Contact Address: Birgit Habermann, International Livestock Research Institute (ILRI), Sustainable Livestock Systems, Nairobi, Kenya, e-mail: b.habermann@cgiar.org

Impact of an extension campaign and the mediating role of women's empowerment on the adoption of agricultural technologies in Uganda

Esther Gloria Mbabazi¹, Awudu Abdulai¹, Enoch Kikulwe², Edward Kato³, Elisabetta Gotor⁴

¹University of Kiel, Dept. of Food Economics and Consumption Studies, Germany ²The Alliance of Bioversity International & CIAT, Uganda ³International Food Policy Research Institute (IFPRI), Uganda ⁴The Alliance of Bioversity International & CIAT, Italy

Research and development interventions promoting agricultural technologies in developing countries are increasing, yet uptake remains low. However, the impact of these interventions on women's empowerment and its role in facilitating adoption is rarely explored, despite women often being highly involved in farm activities. We investigate the effects of an agronomy extension-based campaign executed through a randomised controlled trial on women's and men's empowerment. The campaign employed various methods such as audio, audio-visual, and hands-on approaches for disseminating agronomic information. While the control group received information solely through radio broadcasts, additional dissemination channels were utilised for the treatment group including lecture trainings, drama video shows, demonstration trials, and farmer field days. Throughout the campaign, emphasis was placed on encouraging and supporting the formation of gender-inclusive groups for knowledge sharing, collective marketing, saving, and access to credit. Campaign activities were scheduled in the afternoons and decentralised at the parish level to facilitate women's participation, with at least forty percent of demonstration trials hosted by women. Empowerment was assessed using the Abbreviated Women's Empowerment in Agriculture Index (A-WEAI) tool administered separately to male and female decision-makers in a household. Our findings reveal that the campaign enhanced men's empowerment in resource and leadership domains, leading to increased involvement in credit decisions and participation in groups. Conversely, the campaign significantly influenced women's empowerment through the production, leadership, and time-use domains resulting in increased participation in agricultural decision-making, formal and informal groups, and agricultural production tasks. We further evaluated how women's empowerment in these domains influenced the adoption of soil and water conservation technologies namely mulching, manuring, and trenches.

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

Women's involvement in agricultural decisions and participation in groups significantly influenced the adoption of mulching, a labour-saving technology. Additionally, group participation facilitated the adoption of the three technologies combined. In conclusion, providing farmers with information and involving women in decision-making processes significantly boosts technology adoption among small-scale farmers. These findings underscore the pivotal role of women's empowerment in fostering the uptake of productivityenhancing agricultural technologies among smallholder farmers.

Keywords: Adoption, agricultural technologies, extension campaign, women's empowerment

How mobile apps are transforming smallholder agriculture: Appropriation of mobile apps for fulfilment of smallholder farmers' interests

Farai Alice Gwelo 1 , Naude Malan 2 , Suzall Timm 1

¹University of Johannesburg, Anthropology and Development Studies, South Africa ²University of Johannesburg, Dept. of Business Management, South Africa

Smallholder farmers (SHFs) in South Africa face challenges of limited access to information, inputs, and commodity markets. There is growing focus on mobile apps to improve smallholders' access to vital agricultural information and markets, thereby tackling the key challenges faced by SHFs. Indeed, beyond South Africa, the advent of digital technologies has been welcomed as a possible panacea, pregnant with immense possibility to transform smallholder agriculture. This research critically examined the ways in which mobile apps are transforming agriculture for SHFs access to information in South Africa. The multiple case study methodology guided by the critical theory of technology and self-determination theory was used. Four mobile apps and forty-two SHFs using the apps were purposively selected. The study found that SHFs exercise their autonomy to appropriate both non-agricultural user-generated content apps and proprietary mobile apps to meet their diverse needs and aspirations. This study's findings underscore that by leveraging non-agricultural apps such as Facebook and WhatsApp groups for agricultural purposes, SHFs assert a degree of power and autonomy in their agricultural activities and defy their traditional subservient position in information dissemination and market activities, whereby instead of relying solely on corporate-sponsored agricultural platforms, farmers create their own spaces for communication, knowledge exchange, and market transactions, thereby diminishing the influence of large corporations and promoting alternative grassroot-led avenues for agricultural development and market access. This appropriation of mobile apps enhances SHFs' autonomy by providing them with tools to control their own agricultural activities and decision-making processes, rather than being passive recipients of information or services dictated by external actors, farmers actively shape their digital engagement to meet their specific needs and goals. However, the study also identifies that both user-generated content and proprietary mobile apps can only be appropriated to the extent the design permits, whereby the rigidity of the proprietary apps limits farmers' ability to adapt them to suit their specific needs and contexts, making farmers passive consumers of technology rather than active participants in shaping their digital engagement.

Keywords: Appropriation, Facebook groups, farmers' autonomy, mobile apps, smallholder farmers, WhatsApp groups

Contact Address: Farai Alice Gwelo, University of Johannesburg, Anthropology and Development Studies, Kingsway Campus, 2006 Auckland Park, South Africa, e-mail: faraigwelo@gmail.com

ALBAMAP - Promoting optimal map cultivation in Albania

Eljo Daci¹, Glejdis Hajdini¹, Ilirjan Malollari¹, Dhurata Premti¹, Shamaila Zia-Khan², Klaus Spohrer², Reinhard Peters³, Joachim Müller²

¹University of Tirana, Dept. of Industrial Chemistry, Albania ²University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany ³PiKT GmbH, Germany

Albania is one of the leading countries in the production of medicinal and aromatic plants (MAP) for e.g. therapeutic purposes. Among all MAPs, sage (Salvia Officinalis) and lemon balm (*Melissa Officinalis*) are two of the most important for export. The harvesting of natural stocks still plays the most important role in MAP production, while MAP cultivation is less important. However, the natural stocks are threatened by harvesting, which is why MAP cultivation should be promoted. But farmers often lack the agricultural knowledge to produce MAP of optimum quality. This is particularly true for essential oils, as their quality is poorly reflected in the optical characteristics of the plant.

The ALBAMAP project, an Albanian-German research project, was launched to promote MAP cultivation in Albania. In order to optimise MAP cultivation, a science-to-field approach is applied. The science-to-field approach is based on three pillars. As part of the work of pillar 1, scientific studies are being carried out in the greenhouse and in the field to determine the best fertiliser and irrigation management with regard to optimum essential oil quality. The work in pillar 2 comprises the evaluation of the project developments by means of life cycle assessment and the involvement of all stakeholders. Special importance is attached to farmers and their traditional knowledge. In pillar 3, the development of a control system for optimal MAP production is planned. Irrigation and fertilisation will be automated and plant quality will be continuously monitored using a newly developed optical plant monitoring system. The objective of this work is to present the ALBAMAP project in detail and to show first results. In addition, an outlook on further work is given and a first conclusion of the ALBAMAP project is drawn.

Keywords: Essential oil, fertilisation, irrigation

Contact Address: Eljo Daci, University of Tirana, Dept. of Industrial Chemistry, Tirana, Albania, e-mail: eljodaci@hotmail.it

Map production in Albania - Traditional cultivation and challenges for sage and lemon balm

Glejdis Hajdini¹, Eljo Daci¹, Dhurata Premti¹, Ilirjan Malollari¹, Shamaila Zia-Khan², Klaus Spohrer², Joachim Müller²

¹University of Tirana, Dept. of Industrial Chemistry, Albania

²University of Hohenheim, Inst. of Agricultural Engineering, Tropics and Subtropics Group, Germany

Medicinal and aromatic plants (MAP) have traditionally been used for food purposes and are now also used as ingredients in cosmetics, health products and medicines. Albania is one of the most important suppliers of the herbal raw material and is ranked 16th in the world. MAP production is an important part of the Albanian economy. According to USAID studies, around 20,000 families are involved in MAP collection in natural stocks and 4,000 in MAP cultivation. At least 95 percent of total production is destined for export. Two of the most cultivated plants are sage (Salvia officinalis) and lemon balm (*Melissa officinalis*). The goal of the ALBAMAP project is to develop standards for MAP production in Albania, integrating both scientific expertise and traditional knowledge. Thus the quality, which is important for the world market, shall be consistently increased, making cultivation more interesting and thus reducing the pressure to exploit natural stocks. The focus is on sage and lemon balm, two economically important plants. In order to gain traditional cultivation knowledge of these two plants, 30 farmers in 5 different areas (Perrenjas, Pogradec, Elbasan, Gramsh and Shkoder) were surveyed. The focus was on questions of field preparation and management (fertilisation, irrigation), but also on traditional knowledge regarding harvesting and processing and on assessing the suitability of different locations. Emphasis was also placed on the difficulties and main problems farmer face. The findings from this study will contribute to a better understanding of the current cultivation practices of lemon balm and sage in Albania and it will also give useful ideas and basics for future research and development in this area.

Keywords: Medicinal and aromatic plants, *Melissa officinalis*, questionnaire, *Salvia officinalis*

Contact Address: Glejdis Hajdini, University of Tirana, Dept. of Industrial Chemistry, Tirana, Albania, e-mail: glejdishajdini@gmail.com

Supporting conservation in rural Andean communities: Linking water, human well-being and the sustainable development goals

Johanna Carvajal

University of Cuenca, Dept. of Water Resources and Environmental Sci., Ecuador

Currently, there is an urgent need to conserve natural areas, although the effort invested and the benefits, they provide are difficult to determine. The relationship between ecosystem services, human well-being and the Sustainable Development Goals (SDGs) is poorly understood globally. To address this, examining the daily activities of people is crucial, especially in regions such as the Andes, where the ecosystem service of water provision is essential for rural communities and research is scarce. Thus, the objective was to analyse the relationship between the ecosystem service of water provision, community activities and the SDGs targets. The study area was the Aguarongo Protected Forest located in SE Ecuador at 3200 m a.s.l. This humid mountain forest contains 300 water sources and 60 wetlands, which makes it an important reserve for the supply of water for irrigation, livestock and human consumption in nearby communities. Despite being exploited in the 1970s, the community began to conserve it in the 1990s, making it a case of community conservation of high interest. First, information of the ecosystem service of water provision from the conserved forest, the activities of the communities that use this service and the goals and problems of the communities were recollected thought a story line using interviews to local stakeholders. With these data, we searched for relationships between these components through two indices: Level of support of Contribution and Importance of Contribution using interviews to water users. The results show that the water provision has improved with forest conservation. The activities most linked to this service in the community are diversified agriculture (vegetables, grains, medicinal plants, fodder) animal husbandry for sale and self-consumption, and ancestral health practices. Finally, the SDGs that are most related are those linked to Economic Growth, Food Security, Clean Water and Sanitation and Responsible Consumption and Production. Having a clear understanding of this type of relationship allows us to better understand how conservation can intervene not only at the ecosystem level but also at the community level through the ecosystem service, being decisive for a more sustainable future.

Keywords: Community activities, rural community, SDGs, water provision

Contact Address: Johanna Carvajal, University of Cuenca, Dept. of Water Resources and Environmental Sci., Calle Larga 1-167, Cuenca, Ecuador, e-mail: johanna.carvajal1707@ucuenca.edu.ec

Assessing Farmers' readiness to embrace online social networks as educational tools: Base on TRI

Khadijeh Soleimani¹, Bahman Khosravipour¹, Masoud Yazdanpanah², Katharina Löhr³, Stefan Sieber⁴, Moslem Savari¹

¹University of Khuzestan, Dept. of Agricultural Extension and Education, Iran

²Agricultural Sciences and Natural Resources University of Khuzestan, Iran

³Humboldt-Universität zu Berlin, Thaer-Institute of Agricultural and Horticultural Sci., Germany

⁴Leibniz Centre for Agric. Landscape Res. (ZALF), Sustainable Land Use in Developing Countries (SusLAND), Germany

The considerable potential of social media, particularly online social networks (OSNs), as educational tools and their growing efficacy in knowledge dissemination have been well established. These platforms possess significant capacity for training farmers and expanding their accessibility, particularly in third-world countries. Utilizing social media can substantially alleviate the persistent challenges associated with inadequate access to farmers in developing nations. However, it's crucial to acknowledge the farmers' capacity and readiness to utilise these social networks as educational tools. Hence, understanding the factors influencing the acceptance of these platforms for educational purposes becomes imperative. Addressing these factors can aid planners and policymakers in leveraging the potential of social networks to overcome challenges related to knowledge access, information dissemination, and extension training for farmers, thereby fostering agricultural development.

The present study was conducted to investigate the factors influencing the acceptance of social networks as a promotional educational tool among farmers in Khuzestan province, located in the southwest of Iran. Utilizing the descriptive method and the Technology Readiness Index (TRI) theory, 377 farmers from this province were selected through a simple random sampling method, and data were collected via a questionnaire. Results obtained from structural equation modelling using PLS software revealed that optimism and innovativeness had a positive and significant impact, while lack of comfort had a negative and significant effect on farmers' intentions to use social networks for educational and promotional purposes. Collectively, these variables accounted for 49 % of the variance in intention. Notably, the variable of insecurity did not exhibit a significant effect on intention.

Keywords: Intention, iran's farmers, online social networks, technology readiness index (TRI)

Contact Address: Masoud Yazdanpanah, Agricultural Sciences and Natural Resources University of Khuzestan, Mollasani, 744581 Ahvaz, Iran, e-mail: masoudyazdan@gmail.com

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Utilisation of nut and fruit processing byproducts for sustainable cosmetic formulations: A pathway to microplastic-free beauty products

Binal Dobariya, Dirk Bockmühl

Rhine-Waal University of Applied Sciences, Fac. of Life Sciences - Hygiene and Microbiology, Germany

Microplastic pollution presents a significant challenge to the cosmetic industry, prompting the search for eco-friendly alternatives. This study explores the potential of waste from nut and fruit processing in Central Asia, particularly ground walnut shells (WS) and apricot kernel shells (AKS), as substitutes for synthetic abrasive particles in cosmetics. This project employs innovations and current research to address the issues concerning the use of WS and AKS in cosmetics and to maximise resource efficiency and profitability in the nut processing sector. The research begins with microbial analysis, which provides insights into the microbial quality of the shells. Refining the grinding process to create finely textured WS and AKS powder suitable for cosmetic use. Alternative methods for treating microbial contamination are being developed to ensure compliance with bio-cosmetic standards. Formulation frameworks are customized for foot, face, and rich cream products, with a focus on achieving smooth-edged particles sized between 50 and 100 micrometers. Stability testing confirms the effectiveness and scalability of the formulated products for commercial production. Furthermore, this project highlights the dual benefits of reducing microplastic pollution in cosmetics and reducing waste from fruit processing. The research helps achieve sustainable development goals by addressing environmental issues related to microplastics in wastewater, promoting agriculture, and generating employment opportunities by upholding the circular economy's fundamentals. The study's conclusions have worldwide relevance and mark an important step in the direction of a more environmentally responsible cosmetics sector. The potential for widespread acceptance highlights the significance of creative use of natural resources for a greener future, from Germany to Central Asia and beyond.

Keywords: AKS, bio-cosmetics, Central Asia, Germany, microplastic, resource efficiency

Contact Address: Binal Dobariya, Rhine-Waal University of Applied Sciences, Fac. of Life Sciences - Hygiene and Microbiology, Marie-Curie-Str. 1, 47533 Kleve, Germany, e-mail: binal.dobariya@hochschule-rhein-waal.de

Crop water stress monitoring tools for drip-irrigated rice cultivation with reclaimed wastewater

GREGORIO EGEA¹, ANNKATHRIN ROSENBAUM¹, MARIA MUÑOZ-VILLALÓN², MANUEL J. GONZÁLEZ-ORTEGA¹, MANUEL PÉREZ-RUIZ¹

¹University of Seville, Fac. of Agricultural Engineering, Spain ²Tepro Agricultural Consulting, S.L., Spain

Lowland rice cultivation is characterised by high water demands for irrigation to ensure crop development. Rice in Andalusia is currently grown under flooded conditions. Due to rising temperatures and decreasing precipitation water scarcity is a pressing concern, and solutions for effective water management in rice cultivation systems are imperative. This study investigates the applicability of infrared thermometry and spectral indices for monitoring crop water stress in rice cultivation utilising reclaimed wastewater under varying soil water levels. A field experiment was conducted over two cropping seasons (2022–2023) at the Technological Center for New Water Technologies (Seville). The effluent of the experimental wastewater treatment plant was used for irrigation. The rice was grown in 100 m² plots with three replications per treatment. Climatic data was obtained from a nearby station and crop water requirements were calculated following the FAO-56 methodology. One water metre per treatment was installed to monitor the volume of irrigation water applied. Infrared thermometers and spectral reflectance sensors were installed to continuously measure canopy temperature and vegetation indices (NDVI) in both treatments. Stomatal conductance was monitored via a Leaf Porometer throughout the growing season. Crop temperature and climatic data were used to derive reference non-water-stress baselines to calculate the Crop Water Stress Index (CWSI) in rice grown under aerobic conditions. The reference baselines obtained were stable between 12–17h (local time) and between growth cycles. The CWSI index calculated with the reference baselines derived in this study was sensitive to the variations in crop water status caused by the irrigation treatments. The dynamics of CWSI resembled those observed in stomatal conductance, demonstrating the validity of the method for continuous monitoring of crop water status in the experiment. During early crop development, the CWSI index is inaccurate due to reduced visible soil in the thermal sensor's field of view. The complementary information of the NDVI corrects the interpretation of the CWSI index in early phenological stages. The study highlights the feasibility of infrared thermometry and spectral indices for real-time assessment of crop water stress, offering a valuable tool for precision agriculture and informed decision-making in water management strategies for rice cultivation.

Keywords: Deficit irrigation, infrared thermometry, *Oryza sativa*, spectral indices, thermal sensing, water-use efficiency

Contact Address: Annkathrin Rosenbaum, TEPRO Consultores Agrícolas SL, RDI, Avda. San Francisco Javier, 24, Edif. SEVILLA 1, 3ª planta, 41018 Sevilla, Spain, e-mail: anni@tepro.es

Making climate-smart technologies work for women farmers: Insights from socio-technical innovation bundling approach in India

Prama Mukhopadhyay, Deepali Chadha, Hom Nath Gartaula, Ranjitha Puskur, Kritika Goel

International Rice Research Institute (IRRI), India

Being one of the climate change hotspots in the world, the agri-food systems in India face distinct gender-based challenges to achieve sustainable development goals (SDGs). Women often lack access to resources due to gender and social disparities. This renders them invisible in the traditional and/or formal extension systems, depriving them from participation in exploring and designing solutions to climate change adaptation. The opportunity for skill training, accessing information, and participation in the feedback loop are often plagued with inherent structural biases. This results in undervaluing women's knowledge and work, disregarding their needs and priorities, and dis-appropriately affecting their wellbeing. Consequently, many technologies that are promoted as climate solutions are either not reachable or not usable by them. Therefore, technological advancement is important, but promoting only technologies without the support of inclusive policies and institutions is insufficient in empowering women and building their resilience. While there is a growing emphasis on the importance of engaging multiple stakeholders and bundling various technical and social innovations, evidence on methodologies for enabling such integrations are lacking. Technological development commonly disregards gender considerations, perpetuating a 'gender blind' approach. Drawing from different regions and livelihood systems of India, this paper synthesizes four case studies where the projects and programmes have bundled social, and technical, innovations in their programming. The findings reveal that the interventions described in these cases were designed to facilitate a shift in agricultural practices aimed at mitigating the impacts of climate change, while also challenging gender norms and structural constraints, especially to improve women's economic conditions. Although not originally planned as the bundled set of innovations, the interventions implemented across these cases exhibited a symbiotic relationship and an organic interconnection. Social innovations, which are often overlooked, emerged as an integral component of the bundling process, fostering an enabling environment for women. However, ad-hoc bundling revealed certain gaps, including limited involvement of male stakeholders, insufficient recognition of women's unpaid care work, and a lack of gender responsiveness in designing climate-smart technologies. The study underscores the need for intentional bundling tailored on contextual requirements to ensure sustainable impact, empowerment, and resilience at scale.

Keywords: Empowerment, resilience, social innovation, technology

Contact Address: Prama Mukhopadhyay, International Rice Research Institute (IRRI), Sustainable Impact Department, NASC complex pusa dps marg cg block 1st floor, 110012 New Delhi, India, e-mail: p.mukhopadhyay@irri.org

Digital innovation options for sustainable crop-livestock intensification in sub-Sahara Africa (INNOVAFRIKA concept)

Olivier Kashongwe¹, Mouritala Sikirou², Andrews Opoku³, Tina Kabelitz¹, Barbara Amon¹, Zoumana Bamba², Tim Römer⁴, Thomas Amon¹

¹Leibniz Institute for Agricultural Engineering and Bioeconomy, e.V. (ATB), Germany ²International Institute for Tropical Agriculture (IITA), DR Congo ³Kwame Nkrumah University of Sciences and Technology (KNUST), Ghana

⁴University of Osnabrueck, Germany

Cassava (Manihot esculenta Crantz) is an essential food-feed crop in Africa, and contributes greatly to food security and income. D.R. Congo and Ghana are among the top producers in the world, ranked 2nd (48.77 Mt y⁻¹) and 4th $(25.99 \text{ Mt y}^{-1})$ respectively. In both countries, cassava is produced largely by smallholder crop-livestock farmers. However, due to poor soil fertility, prolonged dry spells, and high pests and disease incidences the average yield of the crop in both countries of about 8.1 tha^{-1} is far low relative to the global average of 30 tha^{-1} . The productivity of the livestock sub-system is also low due to high mortality rates, poor feed quality and improper management practices. The INNOVAFRIKA concept aims at improving cassava-livestock production by using the cassava peels as livestock feed and livestock manure as a fertiliser to increase cassava production in D.R. Congo and Ghana. The cassava-livestock system is conceptualised as a farming system with three sub components, namely cassava production unit, cattle production unit and landholding. A causal loop diagram and system analysis to is used to qualitatively investigate the potential contributions of each sub component. The effectiveness of emerging digital innovations such as image based plant health monitoring, sensor monitoring of cattle performance and geo-referenced fertiliser application, climate smart manure management and sensor monitoring of greenhouse gases emissions from manure are evaluated on the basis of environmental friendliness, economic viability and social responsiveness. The knowledge generated from the project will provide practical steps for inculcating digital innovations into crop-livestock system in Africa for sustainable intensification.

Keywords: Accelerometers, artificial intelligence, cassava brown streak disease, data management, manure management, sensors

Contact Address: Olivier Kashongwe, Leibniz Institute for Agricultural Engineering and Bioeconomy, e.V. (ATB), Max-Eyth-Allee 100, 14469 Potsdam, Germany, e-mail: okashongwe@atb-potsdam.de

New and sustainable innovations to meet the global demand for meat: Cultivated meat as a supplement to conventional livestock farming

Robin Maatz, Philipp Karnop, Andreas Blaeser

Technical University of Darmstadt, Inst. of Printing Science and Technology, Germany The world's population is expected to reach 10 billion people by 2050. This will also increase the demand for meat products. Meat consumption has thereby a negative impact on resource depletion, greenhouse gas emissions and animal welfare. Cultivated meat (CM) is one solution to meet the global demand for meat while improving environmental sustainability and animal welfare. CM is real meat produced under laboratory conditions and represents a complement to conventional meat production. For its realisation, affordable costs per kg are required, for which process steps must be scaled up. The production of structured products, such as beef steaks, needs highthroughput technologies that are capable of producing large quantities while imitating the natural structure of conventional meat. Bio-printing technologies that place biomaterials and cells in a targeted manner to produce three-dimensional constructs are very promising for this purpose. However, the current technologies are only scalable to a limited extent or cannot sufficiently replicate the complex texture of meat. In order to combine high throughput and complexity, we are researching and developing a new bio-printing process, 3D-Bio Screen Printing. In first studies we have shown that hybrid CM products can be additively manufactured from edible scaffolds and living cells with high throughput and high resolution. In order to achieve high nutritional values and reduce costs, plant protein isolates with protein contents of > 20 % can be printed into structured scaffolds. Furthermore, various biomaterials (proteins, fats and polysaccharides) can be built up additively in a multi-layer process to form steak-like texture. In addition, it was shown that meat-relevant cell types proliferate and differentiate on 3D scaffolds and thus expand the organoleptic and nutritional profile as hybrid CM products. Cultivated Meat (CM) combines various scientific fields to address the problem of environmental impact of meat. Innovative technologies are needed for CM to become part of the solution. With 3D Bio-Screen Printing, we present such a technology. As the implementation of CM requires the involvement of the agricultural sciences and agriculture, we would now like to get into an exchange to promote the realisation of CM together.

Keywords: Bioprinting, cellular agriculture, innovation, scaling

Contact Address: Robin Maatz, Technical University of Darmstadt, Inst. of Printing Science and Technology, Magdalenenstraße 2, 64289 Darmstadt, Germany, e-mail: maatz@idd.tu-darmstadt.de

Remotely engineering irrigation schemes in data-scarce project environments: Case study in SNNPR Ethiopia

Derboven Nils

BOKU University, Enviromental engineering, Germany

Effectively engineering irrigation systems remains a challenging endeavour for many agricultural projects in the Global South. While public data for an approximate analysis of appropriate irrigation systems is often available, it frequently remains underutilised. The thesis conducts a case study, estimates the irrigation water demand, and proposes an irrigation layout for the Bonosha farm in SNNPR, Ethiopia. The irrigation water demand for the 84hectare-sized vegetable farm should be drawn from the nearby Bilate River. Among others, the topography of the farm and the soil characteristics outline further requirements for the selection and design of a suitable irrigation scheme. Utilizing the open-access software products FAOstat, QGIS, ClimWat, CropWat, and EPAnet, the thesis exclusively relied on utilising public data to achieve its set objectives. Following the presented approach, engineers, farmers, NGOs, and others are being enabled to approximately engineer irrigation schemes for agricultural projects, independently of the specific financial capacities and the project's data availability. The thesis itself depicts a framework for an approximate analysis of the required irrigation demand and the engineering of a river-based irrigation scheme in data and financially scarce project environments. As the provided framework merely results in approximate solutions that are based on various assumptions regarding influencing parameters, the thesis discusses challenges and opportunities to increase the framework's value and reduce assumptions and uncertainties in the project and the applied models. This framework not only aids in addressing immediate irrigation needs but also serves as a guide for long-term irrigation development in similar contexts. By leveraging open-access software and public data, this approach can democratize irrigation system engineering, empowering stakeholders to make informed decisions and optimise resource utilisation in agricultural projects. Through continuous refinement and collaboration, the framework can evolve to meet the evolving needs of agricultural communities in the Global South.

Keywords: CropWat, EPAnet, Ethiopian agriculture, irrigation framework, net irrigation water demand, QGIS, social empowerment

Contact Address: Derboven Nils, BOKU University, Enviromental engineering, Schaffhausener straße 13, 50935 50935, Germany, e-mail: nilsderboven@gmx.de

Smallholder agriculture takes root in climate action: Evaluating soil organic carbon monitoring

Adaugo Okoli, Athena Birkenberg

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

Voluntary carbon market (VCM) schemes facilitate funding for projects that promote sustainable land management practices to sequester carbon in natural sinks such as biomass and soil, while also supporting agricultural production. The effectiveness of VCM schemes relies on accurate measurement mechanisms that can directly attribute carbon accumulation to project activities. However, measuring carbon sequestration in soils has proven to be difficult and costly, especially in the context of the fragmented smallholdings predominant in global agriculture. The cost and accuracy limitations of current methods to monitor soil organic carbon (SOC) impede the participation of smallholder farmers in global carbon markets, where they could potentially be compensated for adopting sustainable farming practices that provide ecosystem benefits. This study evaluates nine different approaches for SOC accounting in smallholder agricultural projects. The approaches considered involve the use of proximal and remote sensing, along with process model applications. Our evaluation centres on stakeholder requirements for the Measurement, Reporting, and Verification (MRV) system, using the criteria of accuracy, level of standardisation, costs, adoptability, and the advancement of community benefits. By analysing these criteria, we highlight opportunities and challenges associated with each approach, presenting suggestions to enhance their applicability for smallholder SOC accounting. The contextual foundation of the research is a case study on the Western Kenya Soil Carbon Project. Remote sensing shows promise in reducing costs for direct and modelling-based carbon measurement. While it is already being used in certain carbon market applications, transparency is vital for broader integration. This demands collaborative work and investment in infrastructure like spectral libraries and user-friendly tools. Balancing community benefits against the detached nature of remote techniques is essential. Enhancing information access aids farmers, boosting income through improved soil and crop productivity, even with remote monitoring. Handheld sensors can involve smallholders, given consistent protocols. Engaging the community in monitoring can cut project costs, enhance agricultural capabilities, and generate extra income.

Keywords: Carbon accounting, carbon farming, soil monitoring, soil organic carbon

Contact Address: Adaugo Okoli, University of Hohenheim, Inst. of Agric. Sci. in the Tropics (Hans-Ruthenberg-Institute), 70593 Stuttgart, Germany, e-mail: adaokoly@gmail.com

Analysis of the implementation of the policy guidelines for sustainable bovine livestock farming 2022–2050

Danny Fernando Sandoval, Natalia Triana-Angel, Stefan Burkart

The Alliance of Bioversity International & CIAT, Trop. Forages Program, Colombia

Cattle farming among the main agricultural activities in Colombia. However, the extensive nature of this activity generates strong social and environmental impacts such as land grabbing, expansion of agricultural frontier, increased greenhouse gas emissions, and deforestation. One of the main initiatives to promote the productive transformation towards more sustainability are the Policy Guidelines for Sustainable Bovine Livestock Farming 2022–2050 (Lineamientos de Política para la Ganadería Bovina Sostenible; LPGBS), which arose from a series of conversations among sector institutions and the national government. While the LPGBS are presented as the roadmap for cattle farming in Colombia, its implementation raises reservations among the participating institutions in the construction process and faces delays. This research analyses the status of the LPGBS to identify present difficulties and determine strategies to promote sustainability in cattle systems through capacity building. The methodology used is based on a mixed-methods approach. First, a literature review was conducted on studies related to the evaluation of public policies in the cattle sector. This information was complemented with 26 key informant interviews with experts from public and private institutions involved in the design of the LPGBS to obtain key perspectives and practical experiences to understand current difficulties and identify the necessary capacities to achieve the transition towards sustainable cattle farming. The results show that several difficulties arose during the LPGBS design stage: institutional weakness, low participation by government representatives, and little trust among actors were the main challenges during this stage. Regarding early achievements reached during these dialogues, the following were identified: Construction of the criteria for social, environmental, and productive sustainability, consolidation of the sustainability approach at the cattle landscape level, and regional participation. As necessary capacities to develop for promoting the implementation of the LPGBS, the following were identified: promotion of rural extension programs, access to financing programs, and implementation of a traceability system that allows monitoring and evaluation of these programs. These findings highlight the importance of generating policy evaluations in early stages, which allow identifying elements to correct on the fly, which becomes an important input for decision-makers and policy makers.

Keywords: Capacity needs assessment, cattle farming, climate change, public policy, sustainability

Contact Address: Stefan Burkart, The Alliance of Bioversity International & CIAT, Trop. Forages Program, km 17 recta Cali-Palmira, 763537 Cali, Colombia, e-mail: s.burkart@cgiar.org

Improving innovation adoption among African smallholder farmers in West Africa: Implementation research with the "follow the innovation" method

Theodore Asimeng

German Institute of Development and Sustainability (IDOS), Transformation of Economic and Social Systems, Germany

The development and adoption of innovations have been the main driver of economic and social development. Agricultural innovations targeting productivity, resilience, processing, distribution and consumption have enabled development and reduced poverty and hunger. Despite the abundance of innovations, African smallholder farmers tend to adopt innovations much less intensively than those in other world regions to the detriment of their situation, their societies and the environment. This is due to many factors, including but not limited to the large changes beyond the means of farmers and limitations of the physical environment, institutional support and inputs. After many years of post-implementation evaluations to identify why projects could not achieve their intended objectives, implementation research has been the current focus to understand barriers and factors influencing implementation to enhance adoption during implementation. As a result, researchers have been looking into this phenomenon from the point of view of smallholder farmers' demography, psychological biases, innovation development methods, and characteristics of the innovations to understand the low adoption rate. "Follow the Innovation" (FTI) is an implementation research tool that seeks to follow the innovation development process to ensure factors that influence adoption are included in the innovation development process and document why certain objectives were not met to advise future projects. The FTI method is a three-step approach. It considers the barriers and success factors of previous innovations, documents and analyses the current innovation development process, and finally analyses conditions of upscaling and outscaling of successful innovations. This method is currently used in Senegal, Ghana and Benin to follow the development and implementation of five innovations. This paper provides insights into the method and its application for improving innovation adoption among smallholders in the three countries. The practical application of the FTI method demonstrates how implementation research can be adopted to address the factors that hamper adoption and provide lessons for future projects

Keywords: Implementation research, innovation, smallholder farmers, West Africa

Contact Address: Theodore Asimeng, German Institute of Development and Sustainability (IDOS), Transformation of Economic and Social Systems, Tulpenfeld 6, 53113 Bonn, Germany, e-mail: theodore.asimeng@idos-research.de

From afterthought to forefront: Transforming agricultural resilience through co-designed socio-technical innovations

Cosmas Lutomia¹, Eileen Nchanji², Dessalegn Ketema ³

¹The Alliance of Bioversity International & CIAT, Crops for Nutrition and Health, Kenya ²The Alliance of Bioversity International & CIAT, Pan African Bean Research Alliance (PABRA), Kenya

³The Alliance of Bioversity International & CIAT, Crops for Nutrition and Health, Ethiopia

Technological innovation has contributed significantly to addressing challenges posed by climate change on agricultural productivity yet resilience to droughts and other adverse climatic events remains a persistent challenge in rural communities. Although social innovations are recognised as important to enabling technology use, when implemented, they are often considered as an afterthought or rarely bundled with technological innovations. The study used collected from 783 farmers in three counties of Kenya to assess the effectiveness co-designed socio-technical innovation bundles in enhancing the climate resilience capacities of agricultural households. Inferential statistical test of farmers capacities to smooth consumption and quickly return to normal functioning when they experience climate-related shocks showed significant differences between users and non-users of social-technical innovation bundles. 51% of socio-technical innovation bundles users compared to 33 % had moderate to very high capacity (absorptive) to resist and face the immediate negative impacts of the climaterelated shocks. Farmers using socio-technical innovation bundles had higher adaptive capacity than non-users, with 15% of users and 9% recovering speedily (within a month) post-shock. Additionally, significant differences in agricultural output were reported, with users demonstrating higher productivity in maize (545 kg acre⁻¹ vs. 398 kg acre⁻¹) and beans (237 kg acre⁻¹ vs 187 kg acre⁻¹) when they experienced prolonged droughts. The effect of the bundles on productivity was higher when codesigned for both crops – maize $(556 \text{ kg acre}^{-1} \text{ vs } 520 \text{ kg acre}^{-1})$ and beans $(240 \text{ kg acre}^{-1} \text{ vs } 520 \text{ kg acre}^{-1})$ vs. 231 kg acre⁻¹). However, no significant differences were reported regarding the effect of co-designed socio-technical innovation bundles on farming households' capacity to obtain support from community/local groups in times of climate-related shocks. These findings underscore the importance of co-designing and integrating social innovations into existing technological bundles in agricultural programs. Development practitioners and policymakers should prioritise co-designing of socio-technical solutions with direct community participation to optimise climate resilience and agricultural productivity.

Keywords: Adaptation, climate resilience, co-design, Kenya, resilience capacities, sociotechnical innovation

Contact Address: Cosmas Lutomia, The Alliance of Bioversity International & CIAT, Crops for Nutrition and Health, P.O. Box 823, 00621 Nairobi, Kenya, e-mail: c.lutomia@cgiar.org

Development of a multi-criteria-based decision support tool for circular resource recovery and reuse business models

Tosin Somorin¹, Solomie Gebrezgabher¹, Avinandan Taron², Surajidt Ghosh², Shweta Yadav³, Eric Nartey¹, Susanne Bodach²

¹International Water Management Institute, Ghana ²International Water Management Institute, Sri Lanka ³International Water Management Institute, India

The management of waste has emerged as a crucial issue that concerns both public health and the environment, especially in developing countries, where industrialisation is happening rapidly, the population is growing, and policies are inadequate. To promote sustainable development over a long-time frame, global trends advocate for governments, policymakers, and international organisations to explore ways of moving from linear to circular economy (CE) business models. The aspiration is to shift material flows toward zero waste and pollution, where resources are not consumed and discarded but rather valued and retained for as long as possible. The challenge is that implementing CE innovations is often not straightforward, and decisions to transition are often laden with trade-offs and uncertainties. For many decisionmakers and practitioners, CE is viewed as an environmental agenda, and stakeholders' perspectives and priorities on waste management systems are often not considered. This presentation describes the creation of a decision support tool that uses multiple criteria to help decision-makers and practitioners choose suitable and sustainable circular economy business models. It explains the decision analysis methods used to evaluate competing priorities and trade-offs among alternatives. It details how the tool quickly narrows down circular economy business model options for different waste streams and technology alternatives. Finally, it describes a user-friendly interface that allows users to modify inputs, test scenarios, and the operationalisation of the tool in multiple countries and contexts. The target users are public administrators, businesses, and actors involved in recycling food and agricultural waste streams for positive social, economic, and environmental outcomes.

Keywords: sustainable waste management, circular business models, climate mitigation, decision support tool, resource recovery and reuse

Contact Address: Tosin Somorin, International Water Management Institute, Accra, Ghana, e-mail: t.somorin@cgiar.org

Role of network for diffusion and adoption of climate-smart agriculture technologies in Bangladesh

MD REZAUL KARIM^{1,2}, ANDREAS THIEL²

¹Hajee Mohammad Danesh Science and Technology University, Bangladesh

²University of Kassel, International Agricultural Policy and Environmental Governance, Germany

This study aims to unravel the intricate network measures underlying the diffusion and adoption of Climate-Smart Agriculture (CSA) technologies. By conducting personal interviews with both Common Interest Group (CIG) and non-CIG farmers, the researcher gathers rich data on the key actors involved in the diffusion process in the northern Bangladesh. The data analysis for the network visualisation was done by Gephi software. Pearson's correlation of coefficient was estimated to explore the centrality measures that can significantly affect the adoption of CSA technologies by SPSS (Statistical Packages for Social Science) software. The findings reveal compelling insights into the structure and functioning of diffusion networks for CSA technologies. Central actors within these networks emerge as influential figures, playing pivotal roles in disseminating knowledge and catalyzing adoption among their peers. Interestingly, the study uncovers variations in network characteristics and influential actors across different CSA technologies, underscoring the importance of context specificity in adoption dynamics. From network analysis, it is observed that centrality position is a strong predictor of who adopts the different CSA technologies. Active and frequent communication with leaders, early adopters, and lead farmers identified as central actors driving CSA technology diffusion and adoption. Nevertheless, network of farmers is particularly relevant in case of adoption decision for a particular CSA technology, as incentives to use a new crop variety or a fertiliser or a practice are more compelling, if they are connected to potential peers in their network. The results highlight the role of social networks in shaping farmer's adoption decisions, as connections to influential peers and access to relevant information significantly influence the CSA adoption. Overall, the findings show the intricate interplay between social networks and CSA technological adoption, emphasising the need for targeted interventions that leverage existing social structures to promote CSA uptake effectively.

Keywords: Bangladesh, climate-smart agriculture, diffusion and adoption, network, role

Contact Address: Md Rezaul Karim, University of Kassel, International Agricultural Policy and Environmental Governance, Steinstr. 19, 37213 Witzenhausen, Germany, e-mail: rezaulhstu83@gmail.com

Can sustainable intensification boost agricultural productivity and fertiliser use efficiency? Insights from wheat systems in the eastern Indo-Gangetic Plains

Gokul Paudel¹, Jordan Chamberlin², Trung Thanh Nguyen³

¹Leibniz University Hannover, Inst. for Environmental Economics and World Trade, Germany

²International Maize and Wheat Improvement Center (CIMMYT), Kenya

³Leibniz Universität Hannover, Institute for Environmental Economics and World Trade, Germany

Sustainable intensification (SI) is promoted within smallholder farming systems to improve agricultural productivity and reduce negative environmental externalities associated with agri-food systems. In the Indo-Gangetic Plains (IGP) of South Asia, early sowing of wheat has been considered as an important strategy to increase productivity and reduce negative impacts of excessive fertiliser usage, because early wheat sowing can minimise physiological distress associated with terminal heat stress and plants may be more effective at nutrient uptake than late sown wheat. Surprisingly, however, there is a lack of empirical evidence about this coming from on-farm survey data, despite the recognised importance of nutrient use efficiency in the IGP's high-input farming systems. We address this gap by utilising the large-scale farm survey data collected from the eastern Uttar Pradesh and Bihar states of India. We employ an instrumental variable approach to control the potential endogeneity that arises from both observed and unobserved sources of heterogeneity. We find that early sowing of wheat improves all nitrogen, phosphorus, and potash use efficiency ranging from 5–7%, 4–7%, and 3–7%, respectively, as well as 6–7% gain in productivity. However, these impacts are unevenly distributed. Early sowing of wheat on large farms and farms applying doses of fertiliser exceeding the states recommendation are less impacted in terms of gain in productivity and fertiliser use efficiency. Findings suggest that while SI has potential to boost wheat productivity and fertiliser use efficiency, significant policy initiatives are required to minimise the over-application of fertilisers and mitigate the negative environmental externalities associated with agri-food systems in the Indo-Gangetic Plains of South Asia.

Keywords: Early sowing of wheat, fertiliser use efficiency, impact heterogeneity, instrumental variable approach, South Asia

Contact Address: Gokul Paudel, Leibniz University Hannover, Inst. for Environmental Economics and World Trade, Königsworther Platz 1, 30167 Hannover, Germany, e-mail: paudel@iuw.uni-hannover.de

Tropical waste valorisation for sustainable resources: Developing cellulose-based biodegradable paper from coffee and corn husks

Prieskarinda Lestari, Devi Yuni Susanti, Anggitaniko Shiba Dhiyaul Rohma, Ngadisih, Annisa Marsa Chairani, Nathania Clara Dione, Rana Labiba Azzahra

Universitas Gadjah Mada, Dept. of Agricultural and Biosystems Engineering, Indonesia

Paper material has been widely used in various applications. However, the high production and excessive usage of paper may have severe environmental consequences, such as deforestation and improper waste management. This situation must be addressed immediately as it could lead to unsustainable natural resource management practices. Tropical agricultural waste with high cellulose content can be a promising alternative source for biodegradable paper production. Coffee (*Coffea canephora*) and corn (*Zea mays* L.) are some of the leading commodities in Indonesia. The high production of both commodities also generates significant amounts of husk waste that potentially contains high cellulose content. Coffee and corn husks are also generally thrown away without proper treatment, which highlights the importance of waste valorisation. This study aimed to develop and characterise cellulose-based biodegradable paper from coffee and corn husks as tropical waste valorisation. This was intended to explore alternative sources of bio-based material for future paper production, as well as to support sustainable natural resource management.

Six compositional variations were applied with a mixing percentage ratio (% w/w) consisting of A) 75:25:5; B) 50:50:5; C) 25:75; D) 75:25:7.5; E) 50:50:7.5; and F) 25:75: 7.5 (coffee husk: corn husk: polyvinyl alcohol/PVA). This study obtained characteristics of cellulose-based biodegradable papers, including thickness (0.19-0.70 mm), grammage ($38.08-129.39 \text{ g m}^{-2}$), bulk ($3.36-5.40 \text{ cm}^{-3} \text{ g}^{-1}$), whiteness degree (44.86-60.99 % ISO), and water content (4.80-8.72 %). The mechanical properties of the biodegradable paper were also measured, including tensile resistance ($0.04-0.30 \text{ kN m}^{-1}$), strain (0.98-2.20 %), and stiffness (2.80-13.92 mN m). Based on the soil burial degradability test, all paper variations have experienced gradual weight loss ranging from 37.81 to 59.27 % within 28 days, indicating its potential biodegradability. These findings reveal that coffee and corn husk waste can be potentially utilised for developing biodegradable paper from tropical agricultural biomass. This also contributes valuable insight for creating biodegradable paper as value-added bioproducts, with the potential for continuous development in the future.

Keywords: Biodegradable paper, coffee husk, corn husk, valorisation, waste

Contact Address: Prieskarinda Lestari, Universitas Gadjah Mada, Dept. of Agricultural and Biosystems Engineering, Jl. Flora Bulaksumur No. 1 Kocoran, Caturtunggal, Depok, Sleman Regency, 55281 Yogyakarta, Indonesia, e-mail: prieskarindalestari@ugm.ac.id

The impact of demonstration farms on sweet-potato production scale and determinants in Benue state, Nigeria

Innocent Okonkwo¹, Goodness Okonkwo¹, Simon Viashima¹, Charles Chigemezu Nwokoro²

¹National Root Crops Research Institute, Socio-Economics, Nigeria ²ETH Zürich, Environmental Systems Science, Switzerland

This study investigated the influence of demonstration farms on the production scale of sweet potato-based farmers in Benue State, Nigeria, while also identifying the determinants of sweet potato production scale. The choice of Benue State, often referred to as "the breadbasket of the Nation", was motivated by the imperative to bolster sweet potato production in the region, thereby contributing to overall food security in the country. Sweet potato, being a short duration crop is no doubt an important to fight hunger in Nigeria. Using a random sampling technique, 180 sweet potato farmers were selected from a sample frame of 300 farmers, and data was collected through a wellstructured questionnaire. The sample were collected from the three Zones in the State (Zone, A, B and C). The collected data underwent analysis using multiple regression and T-test models. The results of the regression analysis revealed positive relationships between farmers' experience, income, and market access, with farmers' age exhibiting a significant negative relationship at levels of 1%, 1%, 10%, and 5%, respectively. Conversely, the T-test results indicated significant positive relationships for experience, attitude, and income. The study recommends the implementation of training programmes for farmers and the introduction of policies aimed at augmenting farmers' income as strategies to elevate the production scale of sweet potatoes in Benue State and Nigeria as a whole. Furthermore, mechanisation technology will as well improve the farmers attitude towards increasing the scale of sweet potato production in Nigeria. Also, young people should be encouraged to sweet potato production in Nigeria.

Keywords: Demonstration farm, determinants, impact, sweet potato

Contact Address: Charles Chigemezu Nwokoro, ETH Zürich, Environmental Systems Science, Universistatsstrasse 2 lfh2, 8092 Zurich, Switzerland, e-mail: charles.nwokoro@usys.ethz.ch

Terra-i⁺: Satellite-based innovation to monitor agroforestry supply chain sustainability

MINH PHUONG NGUYEN¹, THIBAUD VANTALON¹, PHUONG LUONG THI¹, TIFFANY TALSMA¹, LOUIS REYMONDIN², GIANG PHAM¹, THUY NGUYEN THI THU¹ ¹The Alliance of Bioversity International & CIAT, Vietnam ²The Alliance of Bioversity International & CIAT, France

The EU Deforestation-free Regulation (EUDR) has created an increasing geospatial traceability pressure on agribusinesses exporting to the EU. However, there are inherent shortcomings in existing global earth observation datasets as they often lack the precision necessary for local level analysis. As those datasets often rely on data collected in well documented areas, they run the risk of badly representing vulnerable remote communities. By applying an innovative statistical method and custom artificial intelligence to freely available satellite imagery, Terra-i⁺ establishes a robust methodology to produce high-precision crop-specific datasets that allow for analysis at the farm level, including (1) tree crop cover maps and (2) maps of shade, coffee, and visible soil.

In addition, Terra-i⁺ lowers the capacity barriers to access such geospatial datasets by designing user-friendly interface and creating tailored metrics, such as EUDR compliance, certification compliance, shade tree coverage, and opportunity areas for agroforestry. These metrics enable agribusiness users to make informed decisions about their supply chain, thus increasing transparency and reducing vulnerability of smallholders in the supply chain. Terra-i+ metrics and interface were designed through an iterative prototyping process with agribusinesses as the test users. This process includes identifying key users, shortlisting metrics that most closely meet industry's needs, and multiple rounds of tests and refinements, applying design principles to bridge the gap between science and application.

Terra-i⁺ is currently in use by a global coffee trader. Its innovations help agribusinesses manage deforestation risks in their supply chain and meet carbon commitment, thus actively contributing to the global SGDs 12 (Sustainable production and consumption) and SGD 15 (Life on land).

Keywords: Agroforestry, deforestation, EUDR, innovation, iterative prototyping, remote sensing

Contact Address: Minh Phuong Nguyen, The Alliance of Bioversity International & CIAT, Hanoi, Vietnam, e-mail: p.m.nguyen@cgiar.org

Towards a circular production system in the coconut value chain: Actor, roles, linkage and constraints in Kilifi county, Kenya

Thuranira Muriuki 1, Oscar Ingasia Ayuya 2, Bernard Oloo 3

¹Egerton University, Department of Agricultural Economics and Agribusiness Management, Kenya

²Egerton University, Agricultural Economics and Agribusiness Management, Kenya
³Egerton University, Dept. of Dairy,Food Science And Technology, Kenya

Circular economy (CE) has been recognised as an innovation to resolve coconut waste challenges while promoting economic growth. A transition towards a circular economy is expected to be a shared responsibility among stakeholders. However, there is limited research in relation to the interactions between actors in the coconut value chain. This limits the development of strategies to enhance stakeholder collaboration, therefore hindering the development of policy that enhance extension service delivery. This study, based on the coconut value chain, elucidates stakeholders' perceptions by identifying key actors, their roles, linkages, level of influence, perceived benefits, and potential constraints faced by actors. Data were collected through a participatory workshop and key informants' interviews anchored on Social Network Analysis (SNA). Twenty-one stakeholders and linkages were identified in the information, product, and finance networks. The National Coconut Development Authority (NOCD), Kenya Agricultural and Livestock Research Organisation (KALRO), and the Ministry of Agriculture, Livestock, and Fisheries (MOALF) were the most influential stakeholders in the information network. Farmers and cooperatives are centrally positioned in the product network, whereas finance flow is dominated by the Kenya Revenue Authority (KRA) and the private sector (commercial banks). Despite stakeholders' positive perceptions, several challenges, such as actors' limited knowledge and skills, inadequate funding, and limited market access, impede the transition to a circular economy. To enhance the adoption of a circular economy, this study recommends the formation of more inclusive farmer groups and cooperatives to improve access to information, credit, market linkages, and bargaining power, strengthening the coconut value chain.

Keywords: Circular economy, coconut value chain, Kilifi county, net map, value chain stakeholder

Contact Address: Thuranira Muriuki, Egerton University, Department of Agricultural Economics and Agribusiness Management, 536, 20115 Nakuru, Kenya, e-mail: thuraniraevansmuriuki@gmail.com

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Improving food environments for better nutrition and good health – presentation and discussion of project results

Maja Clausen¹, Dr. Lisa Jäckering²

¹Federal Ministry of Food and Agriculture (BMEL), Division 123, Research and Innovation, Coordination of Research Area, Germany

²Federal Ministry of Food and Agriculture (BMEL), Division 624, International Projects, Twinning, Germany

The human right to adequate food guides the international engagement of BMEL. As such, the German Federal Ministry of Food and Agriculture (BMEL) funding instrument "International Research Cooperation for Global Food Security and Nutrition" has its focus on research for better nutrition achieving the human right to adequate food. BMEL fosters via this instrument more resilient food systems and environments by funding trans- and interdisciplinary research projects that co-create needs-oriented knowledge and elaborate inputs for relevant stakeholders. The Federal Office for Agriculture and Food (BLE) acts as executing agency,

Food environments influence food choices. Increasing accessibility of ultraprocessed foods and nutrition transition, increase the prevalence of non-communicable diseases. In addition, current food systems often fail to provide healthy, sustainable and affordable choices for everyone.

Changing the structure of food environments, hence, affects local consumption behaviour patterns. Reflecting these complex and multiple correlations, BMEL launched the research call "Food Environments for improved nutrition" in 2019. Based on this call, seven international research consortia currently receive funding. During this BMEL Session, three of them will present their research results regarding options to enhance food environments for improved nutrition and health outcomes.

The following researchers have been selected to present their respective project:

- 1. Merle Müller-Hansen, Augsburg University, Germany, project "Appand consumer-based change of food environments for better nutrition and health in India (NutriAIDE)"
- 2. Victoria Kariathi, Sokoine University of Agriculture and Msabila Damian Charles, University of Dar es Salaam, Tanzania, project "Behaviour change to healthy food consumption and physical activity to address the triple burden of malnutrition in a rural-urban comparative study in Tanzania (FoCo-Active)"

Contact Address: Helen Laqua, Federal Office for Agriculture and Food, Unit 334 - Climate, Global Food Security, International Cooperation, Deichmanns Aue 29, 53179 Bonn, Germany, e-mail: helen.laqua@ble.de
3. 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)"

These presentations will be complemented by a facilitated panel discussion and interaction with the audience to exchange experiences and generate recommendations to enhance systemic change.

Keywords: Consumer behaviour, dietary preferences, food environments, nutrition for health, resilient food systems and income, triple burden of malnutrition, women and youth

CropTrust

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Increasing farmers' opportunities to benefit from national seed collections: Experiences of five African national genebanks

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Seeds of change: unlocking the potential of plant genetic material transfer for food and agriculture

TATIANA RIVERA, ROBERT ANDRADE, CAROLINA GONZALEZ The Alliance of Bioversity International & CIAT, Foresight and Applied Economics, Colombia

Conserving and exchanging plant genetic resources in agriculture is crucial for addressing food security, climate resilience, and agricultural sustainability, as it enhances breeding programs. The global exchange of genetic material may result in more resilient and productive crops by combining favourable traits from different genetic accessions. This contributes to achieving SDG-2 Zero Hunger, SDG-13 Climate Action, and SDG-17 Developmental Strategic Financing. This paper explores the prospective economic impact of Colombia's upcoming ratification of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) through an analysis of multiple case studies, illustrating the potential benefits derived from genetic material exchange and the risks involved, along with the fair distribution of benefits through the treaty's multilateral system.

We analyse cases where genetic accession transfer has led to positive outcomes. For instance, in Colombia, the adoption of the TAI8 improved cassava variety has significantly increased productivity, generating benefits worth USD 1.6 million between 2005 and 2022. Without collaboration, results suggest that the costs could outweigh the benefits. The continuous flow of genetic material, facilitated by the CIAT genebank, from other parts of the world into Colombia's research institutions (e.g., government or private) has contributed to the development of improved varieties aimed at ensuring national food security. Moreover, genetic transfers offer potential solutions for present and future challenges, such as developing resistance to diseases like cassava brown streak disease (CBSD) in Africa and Fusarium R4T in banana crops.

While focusing on the benefits of open genetic material exchange, this paper also discusses the importance of equitable benefit-sharing and raises concerns about ensuring the fair distribution of these benefits among stakeholders. The study concludes with a discussion on developing robust seed systems and implementing measures to support sustainable agriculture and food security in Colombia and beyond.

Keywords: Food security, plant genetic resources, seed policies

Contact Address: Tatiana Rivera, The Alliance of Bioversity International & CIAT, Foresight and Applied Economics, Carrera 13 # 1 oeste - 14, 188226 Cali, Colombia, e-mail: t.rivera@cgiar.org

Increasing farmers' opportunities to benefit from national seed collections: Experiences of five African national genebanks

Eva Weltzien¹, Peterson Wambugu², Matilda Ntowa Bissah³, Olabisi Alamu⁴, Sumini Sampa⁵, Yeshitila Mekbib⁶, Matthew Heaton⁷, Nora Castaneda-Alvarez⁷, Evans Ouma⁸, Vinter Achieng Otiego⁹, Joseph

Ndungu², Masiye Tembo⁵, Patrick Attamah¹⁰, Rashied Tetteh³, Mayowa Olubiyi¹¹, Dickson J. Nwosu¹¹, H. Frederick W. Rattunde¹

¹University of Wisconsin-Madison, Agronomy, United States

²*Kenya Agricultural and Livestock Research Organisation (KALRO), Genetic Resources Research Institute, Kenya*

³Council for Scientific and Industrial Research, Plant Genetic Resources Research Inst., Ghana

⁴National Center for Genetic Resources and Biotechnology, Extension and Linkages, Nigeria

⁵Zambia Agricultural Research Inst., National Plant Genetic Resources Centre, Zambia ⁶Ethiopia Biotechnology Institute, Crop and Horticulture Biodiversity Direct., Ethiopia ⁷Global Crop Diversity Trust, Germany

- ⁸Rongo University, Kenya
- ⁹Maseno University, Plant Breeding, Kenya
- ¹⁰Council for Scientific and Industrial Research, Savannah Agricultural Research Institute, Ghana
- ¹¹National Center for Genetic Resources and Biotechnology, Plant Genetic Resources, Nigeria

African smallholder farmers predominantly rely on local biodiversity, locally produced seed of local varieties, to minimise risk and optimise their overall farm outputs in diverse agro-ecological and socio-economic conditions. Farmers' skills, capacities, and culture for managing seed are thus major drivers for adapting their agricultural biodiversity to new threats and opportunities due to climate- and market-developments.

Agricultural researchers addressing these challenges focus on major crops and formal, centralised, seed systems. Biodiversity and the effectiveness of farmers' seed management practices are rarely considered except for the establishment of genebanks. The genebanks were conceived as part of the larger seed and research systems, as a reservoir for genetic innovation focusing on major crops. African national genebanks hold important collections of their agricultural biodiversity, including specialised local crops, local varieties and their wild relatives.

Contact Address: Eva Weltzien, University of Wisconsin-Madison, Agronomy, Madison, United States, e-mail: eva.weltzien@gmail.com

The speed of changes in production conditions, especially in rainfed production systems, requires new crop diversity beyond the reach of local farmer seed systems. Could farmers' access to the diversity held by national genebanks strengthen the innovative capacity of local seed systems?

African National genebanks, supported by the Seeds for Resilience Project, managed by the Global Crop Diversity Trust, explored, in five countries, options to support farmers in their own efforts to use and manage crop diversity for adapting their production systems to the wide range of new, and increasing challenges. Each genebank chose focus regions and crops, conducted stakeholder analyses, identified interested partners and farmer groups and engaged in direct exchanges with these farmer groups. Farmer groups learned about the existence of the genebanks and the crop diversity they hold, and how this diversity can become accessible. Genebanks adapted tools for identifying accessions that may be of interest to specific groups of farmers, and developed approaches with farmer groups to foster integration of useful diversity into the seed systems farmers use. The five national genebanks evaluated their experiences of direct engagements with farmer groups in a workshop. Results of these discussions will be presented.

Keywords: Biodiversity, farmers' seed system, national genebanks

Farmers in Vihiga county, Kenya, transform their food system through multi-sectoral and multi-actor collaborations

Céline Termote, Irmgard Jordan, Francis Oduor, Tosin Akingbemisilu, Lilian Aluso

The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Kenya

Since 2014, the Alliance Bioversity International and CIAT is working in Vihiga County with different stakeholders. An integrated community-based approach was developed whereby communities, guided by researchers, extension workers and County representatives were taken through a series of workshops to co-analyse baseline data on dietary intakes and available agrobiodiversity, followed by identification of barriers and co-creation of local solutions. As a result, community action plans (CAP) for increased farm, market and diet diversity were developed and implemented whereby trainings on kitchen gardens focusing on traditional leafy vegetables (TLV) production, poultry keeping and door to door nutrition counseling were provided by local NGOs, agriculture extension workers in collaboration with trained Community Health Volunteers. Impact evaluation conducted after one year of implementing the CAPs showed that women's and children's dietary diversity scores significantly improved in intervention compared to comparison communities. Despite encouraging results farmers' access to TLV seeds was a major bottleneck whereby desired TLV species/varieties were not available from the formal sector while from the informal sector seed quality was disappointing. Hence, 300 community members formed a community-based organisation (CBO) and established a community seed bank (CSB) where 41 TLV, 50 bean, 26 sorghum and 9 millet varieties were conserved by end of 2023, besides a mother block of 20 fruit tree species. The CSB has since grown into a training and information exchange center, offering platform for business case development. Between 2021 and 2023, the 300 CBO members reached out with seeds and/or trainings on agroecological practices to 8500 fellow farmers, of whom 85% claim to have diversified their farms, 75% improved their diets and their incomes. Meanwhile stunting in the County has gone down from 23.5 % in 2014 to 16.6 % in 2022 due to the multiple actor and multisectoral efforts. Realizing the positive impact on biodiversity conservation, diet quality, and nutrition, the County Government formed a core committee with members from departments of Health, Agriculture and Environment to develop a multisectoral agroecology policy. The Alliance is now guiding this process together with the Intersectoral Forum for Agrobiodiversity and Agroecology (ISFAA) and PELUM.

Keywords: Agroecology, co-creation, community seed bank, food system, food system transformation, Kenya, multi-sector approach

Contact Address: Céline Termote, The Alliance of Bioversity International & CIAT, Food Environment and Consumer Behaviour, Nairobi, Kenya, e-mail: c.termote@cgiar.org

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