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

Tropentag 2022

Can agroecological farming feed the world?

Farmers' and Academia's view

Book of abstracts

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Tropentag 2022

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

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Preface

Tropentag is the largest interdisciplinary conference in Europe, focused on development-oriented research in the fields of tropical and subtropical agriculture, food security, natural resource management and rural development. *Tropentag* takes place annually, even though the past two years were particularly challenging, while the conference had to be organised as an online only event. One of the lessons that we learnt from the virtual conferences is that yes, it is possible to organise it that way, but that it is much better to meet and talk in person. We are thus very happy that this year (two years after what was initially planned), we are able to organise the *Tropentag* 2022 conference at the campus of the Czech University of Life Sciences Prague, Czech Republic, and thrilled that we will again meet all face-to-face, during the 14-16 September venue. However, some of you, due to various reasons, who could not come to Prague, you can still participate at this year *Tropentag*, as all plenary and oral scientific sessions are streamed via the Whova platform, and we also organise several online poster sessions.

This year's *Tropentag*'s confederating theme is: 'Can agroecological farming feed the world? Farmers' and academia's views'. The debates on global food production challenges have become polarised among both scientists and farmers, widening the gap between the advocates of industrial agriculture and global commerce, and the supporters of local food systems and organic farming. While the former claim it is only possible to meet the high production demands through conventional agriculture, the latter are convinced that the world's small farmers can increase yields and final production by adopting techniques that respect natural equilibria and processes and maintain or improve soil health without synthetic inputs. *Tropentag* 2022 will review recent research results that address these challenges from various points of view, with various methodological approaches. Discussions in plenary and thematic sessions, guided poster tours, and workshops will provide participants with new ideas to enhance our understanding of the potential capacity of the agroecological approaches to maintain and restore soil health, conserve biodiversity and adapt to climate changes, and help us face future crises, together with meeting the challenge of feeding global populations.

These aspects will be addressed during the conference by internationally renowned keynote speakers, as well as, by a plenary panel discussion, where you will be able to hear, discuss and confront the ideas of farmers, scientists, and businessmen. Further on, we received $>$ 800 contributions related to the theme of which some 500 will be presented either as oral or poster presentations and are now available in this book-of-abstracts. Apart from 105 oral presentations, clustered in 24 scientific sessions, there

are 36 guided and 14 online poster sessions. Moreover, you can join some of 20 pre- and post-conference workshops and numbers of side events, such as a film festival on pastoralism.

The featured CGIAR centre of this year is AfricaRice, a pan-African Centre of Excellence for rice research, development, and capacity building. It contributes to reducing poverty, achieving food and nutrition security, and improving livelihoods of farmers and other rice value-chain actors in Africa by increasing the productivity and profitability of rice-based agri-food systems, while ensuring the sustainability of natural resources.

We wish to thank all participants for their scientific contributions and our colleagues of the scientific committee for reviewing all abstracts and acting as chairs for oral and poster sessions, but the conference could not be organised without the help of large number of people behind the scenes. We express our gratitude to Eric Tielkes and his team for his very valuable support in organising this ever-growing event. Special thanks go to the student reporters for keeping the blog and reports 'alive'. Thanks also to ATSAF for all the guidance, and to the staff and student volunteers from CZU Prague for helping to organize this venue. Particular thanks to our long-standing donors (listed on the back cover) for their unwaning financial and in-kind support, which allow us to keep conference fees at a modest level, especially for junior scientists. Thank you all for participating - you made it happen again.

We welcome you coming from the many different parts of the world to Prague and wish you an inspiring and enriching conference. Indeed, *Tropentag* is again a whirling pool of people interacting and listening to each other, learning new things, building and refreshing networks, and enjoying science, discussions, food and drink. As of now, let us wish you all the best and enjoy this magnificent event.

On behalf of *Tropentag* 2022's organising team.

Bohdan Lojka, Olga Leuner, Jan Banout, Vladimír Verner, Lucie Ackermann-Blažková, and Patrick Van Damme

Prague, September 2022

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7. Institutions

Plenary speeches

Agroecological transformation of tropical livestock production through improved forages and silvopastoral systems

Jacobo Arango

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Livestock production and consumption of animal foods around the globe are currently under scrutiny, as consumers usually associate these activities to the environmental damage largely caused by extensive cattle ranching and deforestation. However, a change in the narrative is gaining track among key stakeholders giving more visibility to the how livestock foods are produced, differentiating extensive and sustainable cattle raising. Using examples from the tropical belt it can be demonstrated that sustainably managed forages with different strata (e.g., silvopastoral systems) can contribute to all the agroecological principles, mainly recycling, input reduction, soil health, animal health, biodiversity, synergy, social values, and economic diversification. Silvopastoral systems, based in improved forages, have been largely acknowledged for the potential to contribute to climate change mitigation and adaptation. Improved feeds based on mixtures of grasses and legumes (usually local genetic resources) influence modulating the ruminants' digestive microbiota, and hence reduce enteric methane emissions per unit product (kg meat/L milk). Moreover, in a global N fertiliser shortage, agroecological livestock production through silvopastoral systems benefit from the legumes capacity to fix N, with estimates ranging from 80 to 600 kg N per hectare per year, which avoids about 4.5 kg CO_2eq per kg N than if applied via fertiliser. Currently, diverse technologies have been proposed pointing for sustainable livestock production, however, silvopastoral systems stand out among them for the potential contribution to all agroecological principles, increasing livestock productivity while providing ecosystem services, including reduction of the carbon balance of the system.

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Agroecology as a path in the face of chemical dependent agriculture

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With the worldwide economy, particularly after World War II, agriculture started to take on a global scale, not only in the sense that a significant part of the agricultural production started to be globally commercialised, becoming a commodity, but also because it began to become dependent on chemical industries of fertilisers and pesticides and, more recently, on patented seeds.
The industrialisation of agriculture – which allowed agricultural production to be carried out on a very large scale and in a homogeneous way – became known as the "Green Revolution" and had, as a justification for its implementation, the promise of overcoming hunger, through the use of technology.
However, more than half a century has passed and, even so, the only constant still is hunger. Currently, the number of hungry people in the world has increased. In 2020, from 9.2 % to 10.4 % of the worldwide population faced hunger.
Not only has hunger increased, but, in addition, the environment and human health have been intensely contaminated by chemical substances used in agriculture.
To look at the human and environmental tragedy resulting from this agricultural model, let us focus on Brazil, the country that is the largest worldwide exporter of soy, beef, sugar, coffee and orange juice, among other products.
In Brazil, the emblematic expansion of soy – which currently covers an area equivalent to the entire territory of Germany and whose production has grown exponentially – shows us how devastating the monoculture expansion scenario for exportation is.
Between 2010 and 2020, the use of pesticides in Brazil substantially increased by 78.3 %. As a consequence of this increase, we are witnessing chemical violence, oftentimes indirect, silent and subtle, which arises as an unfolding of the aforementioned Green Revolution.
Facing the model imposed by the Green Revolution, which reveals itself to be external, homogenizing, dangerous and colonialist, agroecology appears as an alternative, proposing changes to the way economic processes unfold.
The need for a progressive transition to the path of agroecology is urgent. Otherwise, we will continue on a route that will result in a collision against ourselves.

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"It's the economy, stupid": Why a 1980s American political slogan is a perfect illustration of the drivers for restoration in the Sahel

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The vast drylands of Africa's Sahel region stretch from Mauritania and Senegal in the west to Eritrea and Djibouti in the East and are home to hundreds of millions of people, mostly farmers and pastoralists. Land use systems appear to have been adequate and sustainable for many centuries but were profoundly damaged by colonialism and the subsequent rise of the regulatory state, which emasculated evolved natural resource governance systems. Rapid population growth, serious droughts in the 1970s and 1980s, and maladapted regulatory systems and development priorities have led to a rapid degradation of land and ecosystem health indicators, the progressive worsening of rural livelihoods and a concomitant rise in outmigration and banditry. We propose a number of conceptual principles to apply in the effort to restore these landscapes to high ecosystemic productivity at scale, taking into account the range of modelled changes to local climates. Informed by decades of research and partnerships with development efforts across the region, these principles ask practitioners, regulators, donors and researchers to consider contexts, incentives and drivers, land, tree and livestock management strategies, scale, and nested regulatory and economic governance systems.

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Crops and cropping systems

Crops and cropping systems I

Oral Presentations

Posters

Crop diversification under climate change: a comparative assessment in Ghana, Burkina Faso, Ethiopia and Niger

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Diversified farming systems as an agroecological measure maintain functional biodiversity at multiple spatial and temporal scales in order to be productive, resilient and efficient. However, the potential for transforming or maintaining diversified agricultural systems depends on the ability of the selected crops to be sustained under the climate of the specific areas they are grown. Climate change can affect the ability of one or more crops to grow within specific niches and thereby reducing their potential to be part of a crop diversification strategy. In this study, we assessed the agro-climatic suitability of four major food crops in Ghana (maize, sorghum, cassava and peanut), Ethiopia (maize, sorghum, teff and wheat), Burkina Faso (maize, sorghum, cowpea and peanut) and Niger (maize, sorghum, cowpea and peanut) under current and projected climatic conditions using the ECOCROP crop suitability model. We find that suitability for four crops will decrease in Burkina, Ghana and Niger, while it will increase only in Ethiopia with the magnitude dependent on the climatic scenario. Positive changes in suitability are also projected for three crops in Ghana (up to 26.3 %) and for Ethiopia (up to 7.7 %), while in Burkina Faso area suitable for three crops will decrease (up to -36.8 %) and remain relatively unchanged in Niger(≈ 1 %). Instead, areas that are suitable for only one crop will increase in Burkina Faso, Ghana and Niger, while it will decrease only in Ethiopia. We therefore conclude that the potential for higher crop diversification will be negatively impacted by climate change. The impacts will vary within and across countries and thus, will influence planning for scaling up diversification as an agroecological measure.

Keywords: Climate impacts, crop suitability, farming systems, food crops, multiple cropping

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Crop species richness in homegardens increased in a homestead food production cluster-randomised trial in Bangladesh

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Homegardening can contribute to both food security and dietary diversity of households by increasing availability of and access to nutrient-dense foods, particularly fruits and vegetables. We examined the impact of a Homestead Food Production programme on crop species richness in homegardens as implemented by the NGO Helen Keller International. Around 2700 women in 96 settlements of rural Habiganj, Sylhet, Bangladesh were enrolled in the 'Food and Agricultural Approaches to Reducing Malnutrition' (FAARM) cluster-randomised controlled trial. The Homestead Food Production programme was implemented in the 48 intervention settlements from mid 2015 to late 2018. Over the study period, trained data collectors interviewed women regularly on the number of crop species harvested in their homegardens by season (hot-dry, monsoon, and winter). During the baseline survey in early 2015, we collected annual data on crop species richness for the previous year. Over the ten seasons considered for analysis (from hot-dry 2016 to hot-dry 2019), we collected 31,639 observations of 2,699 women. We estimated the intervention's impact on crop species richness comparing means and using multilevel regression controlling for baseline levels of crop species richness.

At baseline, respondents reported harvesting 6.1 crop species in their homegardens in the previous year, with a slightly higher crop species number in gardens of women later assigned to intervention than to control (6.5 versus 5.8), including 3.7 and 3.3 vegetable as well as 2.6 and 2.3 fruit species, respectively. Comparing the hot-dry seasons from 2016 to 2019, mean total crop species richness was consistently higher in the intervention than in the control group, peaking in 2018 and slightly decreasing in 2019, the year after the intervention ended (all $p < 0.001$): 7.8 vs. 4.0 (2016); 9.2 vs. 5.0 (2017); 12.4 vs. 6.5 (2018); 10.1 vs. 6.1 (2019). The multilevel regression analysis also showed that more crop species – mostly vegetables – were harvested in gardens of intervention than control women in 2016, 2017, 2018 and 2019 (all $p < 0.001$). In summary, the intervention had a positive impact on crop species richness in homegardens, particularly vegetables, not only during the intervention period, but also in the year after the programme ended.

Keywords: Diversity, fruits, healthy food, impact, intervention, vegetables

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Climate change impact on mixed-crop livestock systems in sub-Saharan Africa

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Sub-Saharan Africa (SSA) is particularly exposed and vulnerable to climate risks and therefore warrants a profound estimate of the effects of current and future climate on crop and livestock production to inform policies that may counteract the adverse effects. Therefore, the current study attempts to develop an integrated modelling framework at a farm-scale (IFM-FARM) for simulating the impact of climate change scenarios on the potential productivity of the mixed crop-livestock production systems in SSA. Dominant crops such as millet, sorghum, and maize and total livestock units (TLUs) based on one Representative Concentration Pathways (i.e., RCP 4.5) from the four General Circulation Models (GCMs) namely mbc-cclm-mpiesm, mbc-wrf-gfdlesm, mbc-wrf-hadgem2, and mbc-wrf-mpiesm in Sudan and Savannah zone of SSA were chosen in the study. The time-horizon 1981–2005 and 2020–2050 were considered to represent the baseline and near-future climate conditions respectively.

There was an average decline in the yield of millet, maize, and sorghum by 33.9 %, 28.7 %, and 26.3 % respectively across all the GCMs in 2050 compared to the baseline period. The highest yield loss was estimated for millet and Sorghum to the tune of 65.5 % and 53.2 % respectively under mbc-cclm-mpiesm in the Sahelian savannah zone.

Total livestock Units (TLUs) per hectare increased on average by 81 % in time horizon 2050 compared to the baseline across the two zones and GCMs which could be attributed to the more availability of grass biomass for feed. The results indicate the necessity of tailored management options and agricultural policies promoting the development of short cycled, heat, and drought-tolerant crop varieties and promoting the irrigation schemes in the affected areas.

Keywords: Climate change, integrated modelling framework, livestock, sub-Saharan Africa

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Can low-input agriculture in semi-arid Burkina Faso feed its soil, livestock and people?

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Agriculture in semi-arid Burkina Faso is dominated by mixed crop-livestock smallholder farms with limited investment capacity in production factors (e.g. improved seeds, fertiliser and equipment). Hence, to maintain production, farmers try to make the best use of available resources based on principles of agro-ecology, including crop diversity and nutrient and biomass recycling). We investigated farm-level management of resources (soil, crops, manure, fertiliser and livestock) through time to assess whether the current management options were able to sustain crop and livestock production and fulfil household food requirements. We ran a one-year detailed farm monitoring campaign in collaboration with 22 volunteer farms representing the diversity of the farming system in our study area. We quantified inputs and outputs in the cropping system (244 plots) for one rainy season. In addition, the weekly dynamics of crop residues left on field was quantified up to 12 weeks after harvest. Moreover, inflow and outflow of resources at farm-level were quantified weekly. The cropping system was characterised by a negative nitrogen balance of about 10 kg N ha^{-1} at the farm level. At the field level, cereal-legume intercropping significantly reduced the nitrogen deficit from -23.7 kg N ha^{-1} (sole cereals) to -4.8 kg N ha^{-1}. Dry season livestock grazing caused the amount of crop residue left on the soil after harvest (739 kg DM ha^{-1} on average) to quickly reduce at a rate of 26–76 kg DM ha^{-1} per week, leaving very little mulch as organic amendment. Livestock protein requirements were rarely met from farm-produced feed with average feed gaps ranging between 22 and 94 % of the requirements for small herd and large keepers respectively. Large livestock (cattle) owners relied on transhumance during the rainy season, grazing and frequent purchase of crop residues and concentrates to feed their livestock. Concerning food availability in the household, the amount of grain produced (89–175 % of food required) was generally enough to fulfil household requirements. Our detailed farm data indicates that a better integration of legume crops in the cropping system associated to improved manure and forage management is needed to sustain crop and livestock production.

Keywords: Agro-ecology, crop-livestock, efficiency, farming system

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Urban household vegetable production through the use of a developed vertical garden

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Rice is a major stable in Ghana and there are constant efforts to increase its production locally. As of 2020, local rice production figures were 987,000 tons, an increase of about two hundred tons from 721,465 tons in 2017. This shows a very promising trend in ensuring local production of rice. However, the major rice producers are smallholder farmers whose processes are riddled with drudgery. In addition to ensuring continued production, the smallholder farmers are being introduced to conservation agriculture farming methods. Though they are gradually adopting conservation agriculture methods of production, the level of drudgery in their production still poses major problems for their agenda to increase production sustainably. This study was formulated on the premise that if smallholder rice farmers can own/access machinery easily, it will increase their productivity. As such the study aims at providing a machinery ownership model for smallholder farmers that is economically feasible and sustainable. This was done by first evaluating the level of mechanization through a survey of 150 rice farmers in both the southern and northern sectors of the country. The field data collected from rice production centres in the northern and southern parts of Ghana showed that aside from the major issues with rice production mechanization, only specific processes along the value chain receive attention regarding mechanization. Based on technical specifications, the study provided the full set of equipment (13hp power tiller, drum seeder, knapsack sprayer, mini combine harvester) required to mechanize smallholder rice farming and then further developed economic models around ownership of the machinery. The net present value and cost-benefit-ratio analysis of the business models developed show that the best model is where farmer cooperatives own machinery and hire it out to members.

Keywords: Affordable, growthmedium, low technology, self-watering, vertical garden

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Selection of varieties of deep-water rice for the *cuvelai* system of seasonal wetlands in Namibia

Mark Spoelstra

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In the communal area of north-central Namibia, most residents are subsistence farmers. Pearl millet, the main food crop, provides only low yields, causing frequent famine in Namibia. In the wet season, flood waters flow from the Angolan Plateau through seasonal rivers (*oshanas*), and surface water appears around early January toward the middle of March. The area is utilised by communal farmers as grazing land and the system is called the *Cuvelai* system of seasonal wetlands and covers approximately 800,000 ha, of which 250,000 can realistically be cultivated. The basic idea was not to bring water to the plants, but to bring a suitable plant to the water, i.e., not to redesign the environment with irrigation facilities, but to choose crops that will grow in the given ecosystem. The method chosen was on-site trials carried out at the Ogongo campus of the University of Namibia (UNAM) as well as at the Ministry of Agriculture's Mahenene Research Station, both located in the middle of the wetlands. The National Botanical Research Institute of Namibia (NBRI), located in Windhoek, owns three wild rice species endemic to Namibia. Preselected deep-water varieties from IRRI (International Rice Research Institute) and WARDA (West Africa Rice Development Association) nurseries were tested (n=588). On-farm trials were carried out to see how the rice cultivation fits into existing farm activities. The results are more than promising. The three selected varieties are a short-season, early ripening variety (114–122 days), a late variety (143–158 days) and a variety with awns that defend it against Quelea birds (132–164 days). The selected varieties are reasonably salt resistant. Yields are significantly higher than those of pearl millet. With soil improvement or fertilisation, yields can be increased considerably. So far, there are no rice pests or diseases in Namibia, so its cultivation is purely organic. Wetlands cover 6 % of the earth's land surface and their use is important for food security. Rice cultivation in wetlands can improve farmer's resilience to climatic change by growing an additional crop on underused land, increasing the productivity of agroecological farming by using natural waters.

Keywords: Agriculture, communal areas, *Cuvelai* system of seasonal wetlands, deep-water rice, food security, job-creation, namibia, poverty alleviation , resilience to climatic change, variety selection

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Drivers and pathways of changing rice production systems in Luzon, Philippines

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Estimating future production trends and expected changes in land use and crop management requires an understanding of past and present changes in productivity and of pathways of transitions to the emergence of new cropping system configurations. Understanding and forecasting change trends and their determinants can help avoiding undesirable developments and guide policy decisions for a sustained supply of rice. We studied how recently implemented Rice Trade Liberalization Law (Republic Act No. 11203) in the Philippines changed the policy landscape in the rice sector and impacted rice production systems.

Through a diachronic analysis (years 2018 vs. 2022) we assessed changes in production practices and performance attributes in four main rice-producing provinces in Luzon representing either rainfed or irrigated agriculture systems. Structured surveys administered to 600 rice farmers were complemented by focus group discussions and the sampling and analysis of soil attributes and grain yields.

The law caused the Philippines to be flooded with cheap, imported rice that halved the price of palay (freshly harvested rice) increasing the uncertainties on economic revenues of rice farmers. Just after three years of its implementation, we observed major changes in land use and agronomic practices in the main rice-producing provinces. Mean Paddy area decreased in each site (2–20 %), with significant decrease in Aurora ($P = 0.023$). Least decrease in rice cultivation area was observed in Pangasinan (2 %, rainfed & favorable), whereas highest reduction was observed in Nuava Ecija (20 %, irrigated & favorable). Interestingly, the dry season (DS) crop establishment shifted to direct seeding due to high cost of transplanting in Bulacan (81 %), Nueva Ecija (13 %), and Pangasinan (21 %), whereas wet season (WS) direct seeding increased in Aurora (69 %) and Pangasinan (52 %). N application per hectare decreased in DS Aurora ($P = 0.000$) and Nueva Ecija ($P = 0.049$) and WS Bulacan ($P = 0.05$) and Pangasinan ($P = 0.005$). These might have affected decreased yield per hectare in DS Aurora ($P = 0.000$) and Nueva Ecija ($P = 0.000$) and in WS Bulacan ($P = 0.006$), and Nueva Ecija ($P = 0.010$). We identified new trends and likely drivers at both pre-and post-implementation of the rice trade liberalization law, and highlight major pathways of changing rice production in the Philippines.

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

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Spatial and temporal patterns of agrometeorological indicators in maize producing provinces of South Africa

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Climate change impacts on maize production in South Africa, i.e., interannual yield variabilities, are still not well understood. We here present a pioneer study based on a recently released reanalysis of climate observations (AgERA5), such as temperature, precipitation, solar radiation, and wind speed data. We assess climate change effects by quantifying the trend of agrometeorological indicators (Mann-kendall and sens slope), their correlation with maize yield, and analysing their spatiotemporal patterns (EOF analysis). Thus, we derive the main factors that affected yield variability for the last 30 years (1990–2020) in major maize production provinces, namely Free State, KwaZulu-Natal, Mpumalanga, and North West. Results show that there was a significant positive trend in temperature that averages 0.03–0.04 °C per year and 0.02–0.04 °C per growing season. There was a decreasing trend in precipitation in Free State with 0.01 mm per year. Solar radiation did not show a significant trend in all regions. Wind speed in Free State increased at a rate of 0.01 m s^{-1} per growing season. Yield variabilities in Free State, Mpumalanga, and North West show a strong positive correlation (r>0.43) with agrometeorological variables. Yield in KwaZulu-Natal is not influenced by climate factors. The leading mode (50–80 % of total variance) of each agrometeorological variable indicates a homogenous pattern across the regions. The dipole patterns result illustrate that the variabilities of agrometeorological indicators are linked to South Indian high pressure and the warm Agulhas stream. Its corresponding temporal pattern demonstrates extreme events with strong positive and negative anomalies. Results form this study could be used to assist South Afria's government in favour of policy development to prevent famine due to climate change impact.

Keywords: Agrometeorological, maize yield, spatial-temporal trend

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Ecological status of the Pitahaya crop of the San Jorge farm, Pastaza, Ecuador

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The research developed inserted in the DiveCropS Project: Diversifying Cropping Systems financed by DAAD of Germany, was carried out in the Pastaza province in Ecuador for the study of agricultural practices used in crops. to diversify the production of exportable resources of timber, medicinal or edible species. Within the edible products of this region is the Pitahaya (*Selenicereus megalanthus*) characteristic of subtropical and Amazonian zones, considered an exotic tropical fruit, with yellow skin, pulp with a bittersweet taste, with high demand in the national and international market. The objective of this study was to diagnose the state of the Pitahaya plantations in the San Jorge farm for the introduction of good agroecological practices. The research was based on the descriptive observational technique, which contemplated the application of observation and interview instruments. As results, the plantations were identified in moist, sandy loam soils, with good drainage due to their sensitivity to flooding, applying the traditional trellis system cultivation technique with a height of up to 2 m exposed to high light, with staggered production, achieving five harvests per year, in addition, environmental problems with the crop were detected, where the loss of biological diversity, the felling of forest ecosystems, the use of agrochemicals in the fertilisation of plantations, as well as the opening of access roads, causing the fragmentation of the ecosystem. This situation shows the need to establish a set of agroecological practices to mitigate the impact of environmental problems detected in the crop as a sustainable and sustainable alternative.

Keywords: Agricultural practices, agroecology, cultivation and environmental problems

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Participatory research for agronomic salinity management: Experiences from coastal peri-urban vegetable production in Maputo, Mozambique

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Salinisation of agricultural soil resources is an ever increasing problem for global sustainable food production. Often, it results from interplay of climate change impacts and human agronomic mismanagement. The concept of Saline Agriculture (SA) provides a versatile toolbox of agricultural practices which have the potential to sustain agricultural production under saline conditions and partly even reverse salinisation through soil remediation processes. SA combines diverse soil, water and crop management approaches which intend to improve soil health parameters, in order to minimise salinity levels within the crops' root zone and/or mitigate salinity stress for the plants. However, SA practices are not universally applicable. They need to be tested locally and adapted to the particularities of production systems. Especially smallholder vegetable production systems in (sub-)tropical environments are still rather poorly understood in this regard. Addressing this knowledge gap, an ongoing project initiative is implementing a participatory pilot of SA practices in Maputo's peri-urban coastal vegetable production zones, in southern Mozambique. A consortium of research institutions, farmer associations, agricultural extension bodies and non-governmental organisations conducted an exploratory study to understand the local extent, farmers' perception, and agronomic implications of salinisation in the target region. A mixed method approach was applied, building on stakeholder interviews, field observations, and a participatory soil and water survey. Currently, the project evaluates the local adaptability of selected SA practices in participatory field trials. Preliminary results confirm (a) the pertinence of salinisation as a local driver of land degradation, with salinity levels significantly surpassing threshold levels recommended for vegetable production, (b) a considerable but expandable (tacit) knowledge level on salinity management by the local farming community, and (c) the potential of innovative SA practices to be sustainably introduced into the local production system. The latter include different organic manures, selection of tolerant cultivars, improved fallows with salt tolerant green manures like Sesbania spp. and salinity monitoring with portable soil and water sensors. The presented poster shares these technical insights along with reflections on the participatory methodology of the project, in order to provide impulses for further applied research initiatives on SA.

Keywords: Farmer field school, local knowledge, socio-ecological niche

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Cultivation of niger-seeds – a treasure plant to secure availability of edible oil in Ethiopia

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The availability of edible oil in Ethiopia is limited typical plants as rape or sun flower are not cultivated. Niger-seed (*Guizotia abyssinica* Cass.) is native to Ethiopia and has a very good quality for edible oil, but underestimated in this regard and exported as birdfeed in industrial countries. In northern Ethiopia as in the highland area of Amhara Region niger-seed was cultivated long time by small holder farmers. The aim of this study was to identify land with favourable soil and climate conditions and sufficient water availability for niger-seed cultivation, as well convenient transportation to oil mills. In the field experiments were investigated cultivation methods using the cultivars Fogera and Kuyu, different nitrogen fertilisation in their effect on seed yield, seed quality and postharvest handling, as well as the oil expression efficiency and the quality parameters for niger-seed. The field experiments were prepared in a randomised block for statistical analyses with three repetitions. Based on field study in the locations, Adet and Koga, three seed rates and three fertiliser rates the highest mean niger-seed yield was 1384.6 kg ha^{-1} at Adet location (rainfed) followed by location Koga (rainfed) with 1064.7 kg ha^{-1} and Koga (irrigation) with 967.0 kg ha^{-1} showing significant difference. The seeds were stored in the laboratory for four weeks before the analysis started. Before further laboratory analysis started was ascertained the seed yield (kg ha^{-1}), moisture content (%) (dry basis), thousand seed mass (gram), and total ash content (%). Oil content determination was done for all the three cultivations for comparison i.e. Adet (rainfed), Koga (rainfed), and Koga (irrigation). Fatty acid and vitamin E determination was only done for the Adet experimental station (rainfed). The oil content by experimental location was 41.54 % for Koga (rainfed) followed by 39.59 and 38.67 % for Koga (irrigation) and Adet (rainfed) respectively showing significant difference whereas the Ash content showed a reverse trend of oil content. Fatty acid composition did not show significant difference in any treatment. Significant mean α-tocopherol of 80 mg/100 g (70 to 89 mg/100 g) was determined for increasing seed and nitrogen rates.

Keywords: oil content, seed quality, seed yield, α-tocopherol, oil expression

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Key physiological mechanisms involved in salt tolerance by comparing quinoa genotypes of various geographical origins

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Salinity is the most common problem that limits agricultural productivity in arid and semi-arid regions. One of the promising approaches to cope with salinity problems is the direct utilise of cash halophyte crops. *Chenopodium quinoa* is regarded as a facultative halophyte with a great potential for cultivation in saline regions. The wide range of geographic distribution of quinoa has resulted in significant genetic diversity in salinity stress tolerance among quinoa cultivars. This study aimed to elucidate the individual mechanisms that confer differences in salt resistance to three quinoa cultivars of different origins, namely, the salaries cultivar "Real", the highland cultivar "CICA-17", and the coastal lowland cultivar "NL-6". The quinoa genotypes, varying in salinity tolerance, were sown in sandy soil and directly irrigated with three water salinity levels (0, 150, and 300 mM NaCl) under greenhouse conditions. Eight weeks after the treatments, Plant growth parameters, leaf Na and K content, and photosynthetic measurements were determined. Seed yield per plant was measured at the end of the experiment. Responses to salinity greatly differed among the three cultivars. Plant seed yield was reduced by 47.1 %, 48.5 %, and 11.7 % in the NL-6, CICA, and Real cultivars respectively, at 150 mM NaCl salinity treatment. The Real plants exhibited distinctly the highest K+/Na^+ ratio compared to both CICA-17, and NL-6 plants, suggesting a more efficient control mechanism for K+ retention in Real cultivar. Net CO_2 assimilation rates were reduced by 42.8 % and 49.0 % of the control values in NL-6 and CICA-17 cultivars, respectively, versus only 11.7 % for Real plants. When plants were exposed to 300 mM NaCl, all cultivars showed a sharp decrease in physiological traits and seed yield, with a decrease of 71.7 %, 70.4 %, and 42.8 % in the potassium/sodium ratio in leaves and a reduction of 66.0%, 71.0% and 48.0% in the rates of Net photosynthesis and 84.3 %, 82.3 %, 66.8 % decrease in seed yield of NL-6, CICA-17 and Real cultivars, respectively, compared with the control. These results revealed that Real cultivar is a promising candidate in terms of salt-resistance and seed yield compared to either the CICA-17 or NL-6 cultivars.

Keywords: Genotypes, photosynthesis, quinoa, salinity, seed yield

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Combining mineral fertilisers with compost for sustainable maize production and reduction of greenhouse gas

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Increasing crop production to supply the global food demand without harming the global environment is a major challenge for agricultural sectors in the world. The combined application of organic and inorganic fertilisers has been proposed as a tool for sustainable crop production and reducing greenhouse gas (GHG) emissions. However, interactive effects of fertilisers applied in different ratios on soil nitrous oxide (N_2O), carbon dioxide (CO_2), and methane (CH_4) emissions are site specific. The study aimed to analyse the effects of the combined application of compost and inorganic fertiliser (urea or NPS) in different ratios on maize yield and GHG emission from in Nitisol in Ethiopia at two moisture levels (40 % and 75 % water filled pore spaces) in a laboratory incubation experiment and a two-year field trial. The results showed that maize yield can be increase by about 12 to 18 % when combining organic and inorganic fertilisers compared to inorganic fertiliser application alone. The combinations are also suitable to reduce the emission of N_2O by about 22 to 80 % in comparison to the inorganic fertilisers, especially in wet soil, while CO_2 and CH_4 emissions were less affected. Based on our findings compost application accounting for 40 to 70 % of the N supply in the fertiliser mixtures could be a suitable combination to increase maize yield and reduce N_2O emissions in Nitisols in Ethiopia. Further investigations on farm level are recommended in order to cover a broader spectrum of environmental and management effects.

Keywords: Combined application, compost, greenhouse gases, inorganic fertiliser

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Crops monitoring and yield estimation using sentinel products in semi-arid informal irrigation systems

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The use of earth observation data for crop mapping and monitoring in West Africa has concentrated on rainfed systems due to their predominance in the sub-region. However, irrigated systems, though to a limited extent, provide critical livelihood support to many. Accurate statistics on irrigated crops are, thus, needed for effective management and decision-making. This study explored the use of Sentinel 1 (S-1) and Sentinel 2 (S-2) data to map the extent and yield of irrigated crops in an informal irrigation scheme in Burkina Faso. Random Forest classification and regression were used together with extensive field data comprising 842 polygons. Four irrigated crops (tomato, onion, green bean and other) were classified while the yield of tomatoes was modelled through regression analysis. Apart from spectral bands, derivatives (e.g. biophysical parameters and vegetation indices) from S-2 were used. Different data configurations of S-1, S-2 and their derivatives were tested to ascertain optimal temporal windows for accurate irrigated crop mapping and yield estimation. Results of the crop classification revealed a greater overall accuracy (76.3 %) for S-2 compared to S-1 (69.4 %), with S-2 biophysical parameters (especially the fraction of absorbed photosynthetic active radiation i.e fAPAR) being prominent. For yield prediction, however, S-1 VV polarisation came up as the most prominent predictor in the regression analysis (Radj2= 0.63), while the addition of S-2 fAPAR marginally improved the fit (Radj2= 0.64). Tomato yield in the study area varies up to 1616 kg $m^{-}2$, although about 83 % of the area have yields of less than 10 kg $m^{-}2$. Our study revealed that early-season images (acquired in December) perform better in classifying irrigated crop compared to mid or late-season. On the other hand, the use of early to mid-season (December to February) images for yield modelling produced reasonable prediction accuracy. This indicates the possibility of using S-1 and S-2 data to predict crop yield prior to harvest season for efficient planning and food security attainment.

Keywords: Biophysical parameter, Burkina Faso, random forest, Sentinel, yield modelling

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The potential of integrated soil fertility management for closing the yield gap in Ethiopia

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The dominant farming systems across the Ethiopian highlands includes cereals, notably wheat, maize, teff, sorghum and barley with faba bean being a widely grown legume. Key constraints limiting yields are soil degradation and low soil fertility. The Integrated Soil Fertility Management (ISFM+) Project has collected and analysed data from hundreds of farmer-managed demonstration plots over a 5-year period. These compare farmers' practices (control) with demonstrations using at least three ISFM practices. They included the use of agricultural lime on acidic soils, improved seed, organic fertiliser, rhizobia on legumes, green manure and some inorganic fertiliser. The yields of 1,878 one-year short-term demonstrations, maintained for one season and 103 long-term demonstrations, maintained for five years were measured. The results were used to evaluate the effect of ISFM on grain yields. The mean yield across the short-term control plots was 2.88 Mg ha^{-1} while the ISFM plots yielded 4.81 Mg ha^{-1}, a yield increase of 67 %. Continuous use of ISFM for five consecutive years increased yields by 154 %.Soil acidity had a significant negative impact on control yields, while lime used in the demonstration plots alleviated these effects. It was found that almost all plots would benefit from liming especially in the long-term as acidification increased across the control plots. Comparing control yields to the national average showed no marked discrepancies while ISFM yields were considerably (69 %) higher. With increasing mineral fertiliser prices and a need for more sustainable farming systems, ISFM can pay a key role in agroecological transformation, in alleviating food insecurity, increasing farmers' income and reducing food imports. The 3.5 million ha of acidic soils in Ethiopia could be made highly productive by applying lime and ISFM practices. Scaling up will however require significant private and public investment to ensure access to lime, fertiliser, rhizobia and improved seed. A system of private agrodealers supplying inputs to farmers seems the most likely option to achieve this. Hence the environment for private sector sales of agricultural inputs needs to be improved.

Keywords: Ethiopian highlands, lime, soil acidity, yields

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Phenotyping the banana biodiversity to identify climate smart varieties with optimal market potential in Africa and Europe

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Banana (*Musa* spp.) is the fourth most important crop in the Least Developed Countries, providing staple food for more than 400 million people (www.fao.org.faostat). It is an important source of income for many small and medium-scale producers that needs only limited inputs to ensure a harvest. However, yield and the value chain are far below their potential for many smallholder farmers in the cattle corridor areas (drought-prone) of Uganda. Intensifying banana production in a sustainable way (without expanding land use and considering biotic and abiotic pressure) means introducing suitable varieties that are resilient to the effects of climate change and remain high-yielding. The project, therefore, aims to sustainably improve banana production and productivity with climate-smart bananas. This would be achieved through the diversity search in the already existing banana varieties preferred by farmers. Also through consultations with stakeholders of the banana value chain. But also needed to do is the drought evaluation of recently released elite banana hybrids that are high yielding and also resistant to pests and disease. This would guide the selection and introduction of climate-smart banana varieties that are tolerant to climate change. Introducing diverse banana varieties that are high-yielding with acceptable sensory attributes, resistant to pests and diseases, but also tolerant to prolonged droughts is equivalent to climate-smart bananas. A baseline survey was conducted in Sembabule, Ntungamo, and Isingiro districts. More than 18 % of respondents suffered food and income insecurity, and loss of livestock during drought. The coping strategy reported was a reduction in the number of meals per day and the sale of animals. Also, not all preferred banana varieties were drought tolerant. Intervention; four banana hybrids: Kabana-6H, NAROban^{-3}, NAROban-4, and NAROban-5, identified on the basis of robustness and resilience to erratic rainfall, pest, and disease were established and being evaluated for drought tolerance. The successful banana varieties with tolerance traits to drought will later be promoted to farmers in the drought-prone areas

Keywords: Climate smart banana, high yielding, pest and disease resistant

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Certified seeds or certified bags? Using genotyping-by-sequencing to validate the identity of maize in Ghana

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Since the green revolution in Asia, the adoption of improved varieties is recognised as one of the most important contributions to agricultural productivity and as a critical measure to reduce poverty. Maize contributes largely to food security in sub-Saharan Africa despite persistently high yield gaps. In Ghana, the commercial maize seed market is dominated, for almost twenty years, by one high yielding variety called 'Obatanpa'. The average maize yield is about $1.7\,\mathrm{t\,ha^{-1}}$ whereas its potential is about $4.3\,\mathrm{t\,ha^{-1}}$. As seed quality plays a crucial role in yield performance, in this study, we investigate whether samples sourced from certified Opatanpa seed bags were actually containing the claimed genetic material. Genetic fingerprinting is increasingly used to assess the genetic purity of crop varieties found in farmers' fields, however, this method has been barely applied to commercial seeds so far. In the present study, we used genotyping-by-sequencing (GBS) to compare the collected seed samples (56) from agro-input shops (34) in the north of Ghana, against the reference obtained from the gene bank at CIMMYT in Mexico. Different methods of population structure were performed using the SNP markers, which revealed high variation among the samples and about 11 % of the samples are not relatable to Obatanpa. This study does not explain the reasons for the poor quality of the certified Obatanpa seeds available in the market, however, entry points can be assumed along the entire production chain of the certified seeds and further analysis is needed to identify these shortcomings. Nevertheless, the study stresses the need to sustainably increase the purity of the genetic material available to small-scale farmers in the region, as it is one lever to improve yields.

Keywords: Generic fingerprinting, Ghana, maize, seed system, yield gap

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Does land demarcation affect improved seed uptake? Evidence from farmers' mental models in eastern Uganda

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Do secure land rights incentivize farmers to invest more in their land and adapt their agricultural production to climate change? Many studies investigate this question but come to different results that are highly context-dependent. We evaluate the effect of a pro-poor land mapping and registration project in Eastern Uganda, which supported smallholder farmers in resolving land disputes, demarcating their land and applying for customary certificates of ownership. Specifically, we compare households in a sub-county that benefited from the programme with households in a neighbouring sub-county that did not receive such support. Next to a structured survey, we ask households to draw mental models of their decision process to either use or not use improved seeds, such as drought resistant, high-yielding or early maturing seeds. Mental models capture an individual's perception and understanding of a state or process, allowing to uncover divergences between the observed world and an individual's behaviour. By eliciting mental models, we investigate if and how households that benefited from the land mapping project differ in their adaptation decisions, namely with regard to using improved seeds. Results from 253 mental models show that the decision to use improved seeds involves many different factors. The complexity of the mental models drawn goes beyond frequently advanced explanations of (low) improved seed uptake, which centre on high cost of- and low access to improved seeds. Households who benefitted from the land mapping project more often list secure land rights as component of their decision process, compared to the control group. On average, they also draw more positive connections between secure land rights and the uptake of improved seeds, compared to households who were not part of the land mapping project. In contrast, few households see an influence of land certificates on improved seed uptake, both in the treatment and in the control group. The results lend support to the hypothesis that secure land rights are relevant for increased investment.

Keywords: Improved seeds, mental models, tenure

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Detecting cocoa plantations in Côte d'Ivoire and Ghana and their implications on protected areas

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Côte d'Ivoire and Ghana are the largest producers of cocoa in the world. In recent decades the cultivation of this crop has led to the loss of vast tracts of forest areas in both countries. Efficient and accurate methods for remotely identifying cocoa plantations are essential to the implementation of sustainable cocoa practices and for the periodic and effective monitoring of forests. In this study, a method for cocoa plantation identification was developed based on a multi-temporal stack of Sentinel^{-1} and Sentinel^{-2} images and a multi-feature Random Forest (RF) algorithm. The Normalized Difference Vegetation Index (NDVI) and second-order texture features were assessed for their importance in the Random Forest classification, and their optimal combination was used as input variables for the RF model to identify cocoa plantations in both countries. The Random Forest model based cocoa map achieved 82.89 % producer's and 62.22 % user's accuracy, detecting 3.69 million hectares (Mha) and 2.15 Mha of cocoa plantations for Côte d'Ivoire and Ghana, respectively. The results demonstrate that a combination of an RF model and multi-feature classification can distinguish cocoa plantations from other land cover/use, effectively reducing feature dimensions and improving classification efficiency. The results also highlight that cocoa farms largely encroach into protected areas (PAs), as 20 % of the detected cocoa plantation area is located in PAs and almost 70 % of the PAs in the study area house cocoa plantations. These findings highlight the urgent need for governments and buyers to address both the distal and the proximal causes of cocoa-related deforestation.

Keywords: Cash crops, cocoa mapping, encroachment, protected areas, West Africa

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Assessment the impact of dikes on economic efficiency of models for rice farming in Dongthap, Vietnam

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The study was carried out in four districts Hongngu, Tamnong and Thanhbinh, which are located in the northern area of Tiengiang river of Dongthap. This is a province in South-Vietnam, with strong flooding by the Mekong River. Because flooding has a large influence on the farms and food production, policy tried already since long time to find solutions to solve this problem. One solution is to set up a branched canal system and a high-density dyke system, in this region important for rice and many other crops. Two main types of dike has been researched, are: (1) the mezzanine dike, a short low dike system, can receive floods to build up alluvium for fields; and (2) the thorough embankment, a high dike system which can completely protect the cultivated crops and farmers from floods. In this region, diking is a good possibility to exploit fully the arable land, for example rice could be grown 3–4 crops per year, vegetables could be grown 6–7 crops per year. However, in a long term it cause the land to be exhausted. However, in a long term it can cause the land to be exhausted. The area inside the embankment is often over-exploited, the concentration of chemical fertilisers in the soil is high and the soil fertility is reducing because floods were reduced for many years and the field cannot receive fertile alluvium soil. This is the main reason for the significant reduction in crop yield and impact to the economic efficiency. The aim of study was to determine the positive and negative aspects of dike system in order to propose a reasonable and profitable agricultural production complex model, which consider the valuable crops, the season and the consumer market. It has to consider, the influence on productivity and cultivated effect depend on the operation of the dike, floods and the environmental quality inner area of dikes. The economic efficiency of production models was evaluated by several parameters, including: Production value GO (Gross Output); Basic investment; Intermediate expenditure (IE); Value Added (VA); Mixed Income (MI) and Profit (Pr). The estimation based on the questionnaires and model monitoring datum.

Keywords: Dike systems, farming system, flooding, Mekong delta, multi factoral models

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Synthesis of field experiments for the assessment of yield response to different management options in diverse agro-ecological zones in Kenya using the CERES-Maize model

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Maize production important in sustaining the livelihoods of approximately 98 % of smallholder farmers in Kenya. The production, however, has been declining as a result of periodic climate shocks, pests, diseases, declining soil fertility, and poor agronomic practices. Aligning maize production to feasible management strategies is important for low production regions of sub-Saharan Africa.

In this study, therefore, we synthesized field experiments conducted in the 2014 and 2021 growing seasons in the Endebess region in Kenya and three other well-calibrated and evaluated experiments conducted in Embu, Juja, and Naivasha during different maize growing seasons. Subsequently, we determined yield responses to strategies that include three fertilisation rates (N = 50 kg ha^{-1}, N = 75 kg ha^{-1}, and N = 100 kg ha^{-1}), two irrigation management (rainfed and supplementary irrigation of 80 mm), and three sowing dates (15th March, 1st April, and 15th April) using the DSSAT model (CERES-Maize). In total, we simulated 18 treatment combinations using long-term (1984–2021) weather data and computed the average yield.

Results show a varied response of the different strategies to maize production based on the agro-ecological zone. Under rainfed production and the recommended fertilisation rate of 75 kg N ha^{-1}, CERES-Maize simulated yields of 5835 kg ha^{-1} and 4389 kg ha^{-1} for Endebess and Embu, respectively. However, simulated yields in Juja and Naivasha were 3105 kg ha^{-1} and 2899 kg ha^{-1}, respectively. The yields, however, increased by 27 % and 36 %, under supplementary irrigation and the recommended fertilisation rate. The relatively humid regions of Endebess and Embu showed little effect on supplementary irrigation (+5 % and +4 % yield increase), while a high fertilisation level of 100 kg N ha^{-1} improved yields by 15 % and 19 %, respectively. This shows that in the upper midland agro-ecological zones in Kenya, nitrogen is the limiting factor for maize production, whereas moisture stress is attributed to low production in the lowland regions. Evaluation of the sowing dates shows that early planting (15th March) combined with supplementary irrigation is beneficial only to the lowland regions. The results imply that accounting for site-specific conditions is necessary for improving maize yield in Kenya.

Keywords: CERES-Maize model, management strategies

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Patterns and drivers of medium-term agricultural landscape transformation in Kyunsu township, southern Myanmar

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Kyunsu township in southern Myanmar comprises coastal regions and a multitude of small islands covered by vast tropical evergreen forests, mangrove forests, and a large water body in the Adman Sea. Due to population growth, residents are increasingly expanding their agricultural areas. Understanding the patterns and drivers of medium-term agricultural landscape transformation in this area is crucial for local policy making to foster sustainable crop production. Landsat datasets were used in a comparative post-classification approach to investigate agricultural landscape transformation over 40 years. Iso-cluster unsupervised classification, supervised random forest classification, compilation of classified data, and digitisation of Landsat datasets from 1978, 1989, 2000, 2011, and 2020 were performed using ArcGIS software and GEE platform. A minimum of 58 training points and 65 training polygons for each class were used for supervised classification. The overall accuracies of the classification were 96 % (1978), 97 % (1989), 97 % (2000), 97 % (2011), and 97 % (2020). As expected, the results did not indicate notable changes in water bodies (+0.11 %) within the last 40 years. However, major changes were noted in lowland rice fields (+90 %), open forests (+81 %), settlement areas (+115 %), aquaculture (+1594 %), and other land uses (+188 %) while closed forests shrunk by 45 %. Also, minor changes occurred in mangrove forests (-9 %) and in plantation areas (+11 %). Change detection showed that 54.56 km^2 of lowland rice areas were expanded to open forests, mangrove forests and plantation areas and 229.26 km^2 of open forests, closed forests, and mangrove forests were turned to plantation areas. A large proportion of closed forests (405.23 km^2) transformed to open forests. Population growth with settlement areas expansion could be the major driver of agricultural landscape transformation and consequent deforestation in this area. Local land-use planners and extension services should foster agroecological cropping practices to improve crop productivity per unit land area for livelihood security of the local people while making the policy to maintain natural forests for ecosystem services.

Keywords: Crop land expansion, deforestation, ecosystem protection

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Agro-ecological water and crop management practices' effect on rice yield and water productivity in lowlands: a meta-analysis

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Climate variability frequently leads to water scarcity in agriculture in general and rice growing in particular. There are many adaptation techniques developed for rice cultivation by diversifying production environments and increasing water management practices. Nevertheless, little is known about their performances. This meta-analysis aims to evaluate the crop management performances of various water management practices in lowland rice cultivation worldwide. We conducted research using Scopus and web of science databases with the keywords << irrigation AND "water productivity" OR "water use efficiency" AND rice* or paddy AND lowlands OR plains OR "Inland valley" >>. The criteria applied are essentially the language (English or French), the year (2000–2021), and the type of document (peer-reviewed papers). A total of 56 articles out of 441 met these criteria, from which 573 Observations were collected. Five (05) water management practices were identified in lowland rice as follows: Continuous Flooding (CF), Saturated Soil (SS), moderate Alternative Wetting and Dry (AWDm), severe Alternative Wetting and Dry (AWDs), and Aerobic rice (AR). We compared SS, AWDm, AWDs, and AR practices to CF. The response ratio of the yield and water productivity (RR) were used as measures of the effect sizes of the response of water stress on rice yield and water productivity. Our study revealed that yields decreased by 11.1 % and 37.5 % respectively in the AWDs and Aerobic systems compared to CF. While on saturated and AWDm practices, the differences in performance compared to CF are not significant ($p > 0.05$). Water productivity increased by 25.7 %, 32.9 %, and 25.6 % under AWDm, AWDs, and Aerobic systems, respectively. Findings also showed that rice yield and water productivity were significantly improved with rice short genotype cycle, in' direct sowing under AR practices and higher plant density (]75;100]). Meanwhile, the best water productivity (49 %) was observed under AWDs system when rice is transplanted with plant density 25 plants m^{-2} The implementation of the AWDm practices allowed to improve water productivity by 25.7 %, while maintaining rice yield.

Keywords: Aerobic rice, agroecological water management practices, alternative wetting, and dry, continuous flooding, rice, soil saturation

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Comparative characterisation of humic substances obtained from anaerobic digestate of horticultural residues

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Currently, agriculture has as one of its main objectives the reduction of the use of agrochemicals, since their constant application causes damage to the environment and human health. Among the products that have been used to increase crop yields are bio-stimulant products. Humic substances have been recognised for their bio-stimulant action and direct impact on plant physiology. One of the ways of obtaining humic substances is from the anaerobic digestate obtained by anaerobic digestion. Compared to commercial products, humic substances from anaerobic digestate contain a wider variety of organic substances, more lipids, more nitrogen and a lower degree of oxidation. In this study, the humic substances obtained from anaerobic digestate of horticultural crop residues for their use in agriculture were characterised. Anaerobic digestate samples were subjected to a basic treatment with sodium hydroxide (NaOH) at concentrations of 0.1 mol, 0.5 mol and 1.0 mol that allowed the separation of humic and humin substances. For this purpose, three solid/liquid fraction ratios (1/8; 1/10; 1/12) were used. Then, the separation of humic acid and fulvic acid by acid extraction with hydrochloric acid (HCl) was performed. The physical-chemical characterisation of the humic substances showed the high potential fertiliser value due to their contents of N, P, K, and micronutrients. However, the proportions of N-P-K in both humic substances were widely variable; meanwhile, the micronutrients were below the recommended limits for the concentrations of potentially toxic elements. In conclusion, the humic substances obtained from the anaerobic digestate showed substantial differences in terms of nutrients and physicochemical characteristics. Future perspectives indicate that nutrient variability in bio-based fertilisers will be one of the greatest challenges to address in the future utilisation of these products.

Keywords: Anaerobic digestate, horticultural residues, humic substances

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Do agro-ecological practices improve water productivity in irrigated vegetables crops?

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Performance of irrigation systems are suggested better crop yield and irrigation water use efficiency (IWUE) when combined with agroecological practices. These practices aim at a sustainable soil, water, and crop management by improving soil root zone environment and increasing crop water and nutrient absorption. However, the effects of agroecological practices on crop yield and IWUE are variables. This study presents the results of meta-analysis of 25 peer reviewed scientific publications on irrigated vegetables that met eligibility criteria. A total of 282 observations extracted was used with random-effects model to compute response ratio (RR) of vegetable yields and IWUE. It aims to assess whether irrigation application methods, relative irrigation amount, season, and crop types significantly improve crop yields and IWUE under deficit irrigation (DI) and over full irrigation (OFI) compared to full crop water requirement (100%ETc) as the control. Both gravity and pressurized irrigation have a negative impact on vegetable yields under DI or OFI. IWUE is improved when DI is applied under pressurized irrigation compared to gravity application while in OFI, both water application methods lead to a significant decrease of IWUE by 240 %. Over full and deficit irrigation have a significant negative impact on vegetable yield (RR DI=-0.1388, $p<.0001$; RR OFI=-0.0437, $p<.0001$). The effect is 200 % more severe when DI is applied compared to OFI and under 50 % of ETc. Among the different irrigation amount applied, only an application between 50 and 80 % of ETc resulted in the best IWUE. Yield is negatively affected as opposed to IWUE regardless the fertiliser source used under DI and OFI. Indeed, IWUE is most improved when organic fertiliser is applied alone or in combination with mineral fertilisers. Crop types and production season also negatively impacted yield under DI or OFI, but water productivity is improved under fruit vegetables and spring-summer season. Our findings highlight the potential of agroecological practices under irrigated vegetable to increase yield and WUE and identify in which conditions these results can be achieved. These practices can be used successfully around the world.

Keywords: Agroecological practices, irrigation methods, relative irrigation amount, vegetable, water use efficiency

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Identification and characterisation of salt stress-responsive NHX gene family in chickpea

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Chickpea (*Cicer arietinum* L.) is commonly recognised as a garbanzo bean. It has a nut-like flavour and is a most valuable and nutritious food crop for the globally increasing population. The annual production of chickpea is 11.5 million tons and has the third rank after common beans. Salinity has an adverse influence on chickpea germination, vegetative growth, and reproductive activities. Plant adapts the strategies to cope with the salinity stress. Na^+/H^+ exchanger (NHX) is one of the gene families which has been well known to improve salt tolerance in plants. NHXs are membrane transporters that catalyze the electroneutral exchange of K^+ or Na^+ for the accumulation of H^+ and are important for pH and ion homeostasis and salt tolerance. The aim of this study was the identification and characterisation of the NHX gene family to identify the salt stress-responsive NHX genes in chickpea. We identified the eight salt stress-responsive NHX genes from chickpea on a genome-wide scale. The phylogenetic analysis represented the evolutionary relationship of CaNHXs with other species, and the intron-exon organisations analysed by gene structure analysis revealed that CaNHX7 and CaNHX8 have a high number of introns and exons. Subcellular localisation, protein-conserved motifs, and domains were examined. In silico gene expression analysis revealed that out of eight members of the NHX gene family, two members CaNHX3 (Ca_19073) and CaNHX7 (Ca_02050) have shown high expression under salt stress. Overall, this study provides the specific targets for further comprehensive functional study and identified that CaNHXs may be explored further as potential gene candidates for the improvement of chickpea.

Keywords: Chickpea, expression analysis, gene family, Na^+/H^+ exchanger (NHX), salt stress

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Optimum planting dates and season length for maize in Kano, Nigeria

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Maize is a staple food crop in Northern Nigeria and most of the cropping is under rainfed farming. Rainfed farming is susceptible to climate change. Climate change has impacts on rainfall and temperature variability which has a significant impact on maize yields. There is therefore need for continued research on strategies to improve climate change adaptation in maize. One such strategy involves the use of low-cost strategies such as planting dates and variety choice. The study was based in Northern Kano, which is the maize belt of Nigeria and used historical climate data (1980-2020) from NASA as input data. Using the DSSAT 4.7 crop model planting series were undertaken every 10 days from 1 May to 31 August each year. Simulations for yields were undertaken at each planting date each year across the Kano State, Nigeria. The planting date with the highest yields each season was considered the optimum planting date. The study also assessed season length at scale by computing the difference in season commencement and termination of effective rainfall (1980-2020). The DSSAT model simulations were undertaken at scale of 10 km^2across the state. Generally, in northern Kano the optimal planting dates range from 20-May to 29-June. This was more notable in the years 1985, 1990, 1995, 2010, 2015 and 2020. In 2000 and 2005 the optimal planting dates were generally delayed across the state and ranged from 29-June to 8-August. The season length is generally shorter in northern Kano compared to southern Kano. The season length in northern Kano ranged from 80-110 days. Northern Kano is therefore suitable for short to medium season length varieties. In contrast the season length was 110 to 130 days in southern Kano. Southern Kano is therefore suitable for medium to long seasoned varieties. The study concludes that there is need for use of different varieties in different areas of Kano to ensure considerable yields across the state. Similarly, use of optimum planting dates by farmers will lead to relatively high yields. There is need to include seasonal forecast data for use in determination of the optimum date and season length.

Keywords: Crop model, planting date, season length, variety

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Potential use of sago (*Metroxylon sagu*) for feed and agro-industry

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Innovation in our way of thinking can create new models that adapt to current conditions and use consciously local resources to their full capacity.
Therefore, making the most of a resource like sago (*Metroxylon sagu*) can be a solution to many problems faced in modern agriculture. Its importance lies not only in its wide distribution throughout Southeast Asia, and thus its proximity to the lifestyle of consumers but also in its multifunctionality. Among its most important uses are as livestock feed, as a natural fertiliser, and for bioethanol. Unfortunately, the sago habitat has been decreasing over time due to the land use change into estate crops that can bring more income. This study aims to review the potential use of sago to support the sustainability of food systems and forest ecosystem services.
Besides its uses in the food sector, sago *hampas* (the fibrous residue of the starch production) can act as livestock feed, due to the fact that it entails a high fiber content of 65.7 % starch, 21 % lignin and 20 % cellulose. It can be further used as an absorbent for heavy metals like chromium and mercury and waste spillage in the sea, as well as in the bioethanol production, with the benefit that the higher octane facilitates a smoother glide in combustion engines. Furthermore, the wastes of the sago consuming animals, mixed with the leftover remains of the palm can be used as fertiliser. These are mixed with poultry waste to introduce something called "*co-composting*". The sago starch can be further fermented using *Lactococcus lactis* to create L-lactic acid, which can be used to create biodegradable thermoplastics and skin care, toiletries, and hair care products.
In conclusion, sago is not only a product that grows in abundance and adapts easily to swampy ecosystems, which could help to conserve the biodiversity of the area, but it also has countless uses as a biodegradable material in agro-industry, pharmaceuticals and the automotive industry.

Keywords: Agro-industry, *Metroxylon sagu*, Southeast Asia, sustainability

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Crops and cropping systems II

Oral Presentations

Posters

The effect of alternate-wetting-and-drying irrigation (AWD) on rice phenology and yield

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In the Vietnamese Mekong Delta, an alternative water management strategy is needed to maintain the productivity and sustainability of triple cropping rice (*Oryza sativa*) systems. During the dry season, water saving irrigation technologies, such as alternate wetting and drying (AWD), reduce methane (CH_4) and nitrous oxide (N_2O) emissions due to periodic soil aeration while reducing freshwater use. To evaluate potential yield penalties caused by AWD, field trials were established over two years in the Mekong Delta, Vietnam, in which 20 rice varieties were grown under fully irrigated and 'safe' AWD conditions and yield and yield components were determined. The varieties comprised a selection of twenty commonly cultivated and soon to be released Vietnamese rice varieties and were grown for two successive dry seasons at the Loc Troi agricultural research station in collaboration with the BMBF project, RiSaWa. During both seasons we measured yield components, yield, and water level. We observed a slight, but significant ($p > 0.001$), yield reduction, 7 % on average, across all varieties grown under AWD. Analysis of yield components showed that across all varieties under AWD, rice plants grew more tillers, produced fewer panicles and spikelets, suffered greater sterility, and had a lower 1000 grain weight. Varietal difference could in part be attributed to varying development rates, which exposed certain varieties to a more severe water deficit during key phenological stages. Based on the number of days that overlapped with a phenological stage of a variety, we found that there was a significant ($p > 0.05$) relationship between the number of days exposed to the dry down period during panicle initiation and the spikelet number. Considering the field is already kept flooded during flowering, practitioners of AWD should take other phenological stages into account when scheduling irrigation events. Potentially under 'safe' AWD', the start of AWD could be delayed until after panicle initiation, and the field could be allowed to dry during flowering.

Keywords: Alternate wetting and drying, Vietnamese Mekong Delta, yield component compensation

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Experimental development of a hydroponic nutrient solution based on organic residues

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Bioponics have a great potential to replace mineral fertilisers and offer a strategy for reutilising nutrient-rich organic residues. This study aimed at developing a balanced organic nutrient solution for lettuce, based on different organic waste materials with known N, P, K contents with minimal technical effort. Two different recipes were prepared: (1) containing animal bone meal and goat manure (R1), and (2) based on R1, augmented with potato- and banana peel (R2). To extract the nutrients ingredients were mixed with water according to recipe and digested over 25 days. The experiment comprised aerated (aerobic) and non-aerated (anaerobic) digestion either pH uncontrolled or pH manually kept at pH 6.5, with three replicates.
Samples of the digestate were taken every third day, and NH_4^+, NO_3, K, and PO_4^{3-} concentrations were analysed. For the pH-controlled samples, pH was adjusted at the same interval.
Mineralisation rates differed strongly between digestion method, pH treatment, and the minerals N, P, and K. Anaerobic treatment showed a higher N mineralisation. The mineralisation was promoted by the lower pH in anaerobic conditions since NH_4^+ mineralisation negatively correlated to the pH with correlation factors r = - 0,6 (R2) respectively - 0,79 (R1). Although highest N mineralisation was observed for R1 under anaerobic, pH-controlled digestion, only 11 % of the N contained in the organic substrates was converted into NH_4^+.
P was mineralised slowly over the entire time of observation. Again, a negative correlation to the pH was observed. Mineralisation was highest for the anaerobic and the pH-controlled aerobic treatments. The highest conversion of the organically bound P into PO_4^{3-} with 23 % was measured for R1, anaerobic, pH-controlled digestion at day 22.
Almost all K was mineralised within a short time for both recipes and treatments. The pH value did not influence K mineralisation. Neither recipes nor digestion treatments resulted in well-balanced nutrient solutions for hydroponics.
This study provides, however, relevant information on the mobilisation of main plant nutrients, the role of the pH, and digestion treatments. The findings serve as the basis for subsequent research to increase mineralisation rates and optimise the nutrient ratios of the mixtures.

Keywords: Bioponics, hydroponics, nutrient mineralisation, plant nutrition, reutilisation

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Increasing rice yield and profitability through salt-tolerant rice varieties and nutrient management practices under salt-affected soils in irrigated rice systems in the Sahel

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Soil salinity is one of the major constraints to irrigated rice production in the Senegal River Valley. Several technologies including salt-tolerant varieties and nutrient management practices have been developed but have not been widely adopted due to a lack of farmers' participation in their development, testing, and dissemination efforts. The objective of this study was to assess the agronomic and economic viability of improved salinity management options compared to recommended management practice and farmers' practices. A series of experiments were conducted in both Research Station and farmers' fields using Farmer Participatory Approach over two years (2020–2021) in dry and wet seasons in the Senegal River Valley. There were five treatments including T1: Typical practices (Sahel 108, broadcasting and NP); T1 + potassium input (T2); T2 + Gypsum + Zinc (T3); NPK + Salt-tolerant variety (T4), and T4 + Gypsum + Zinc (T5) in on-station trials in saline soils with EC value 2 dS m^{-1}. Additionally, a total of 170 on-farm trials were conducted. Farmers were asked to choose the treatment (s) among those evaluated on-station, and these treatments were compared with their current practice. On-station results showed that improved management options T3, T4, and T5 outperformed T1 by an average of 1.1 t ha^{-1} (31 %), 0.7 t ha^{-1} (20 %), and 1.8 t ha^{-1} (49 %), respectively. Compared with the current farmers' practice (4.5 t ha^{-1}), average grain yield increased by 0.8 t ha^{-1} (16 %) in on-farm trials. The net profit was about 107 USD ha^{-1} greater with improved salinity management option compared to farmers' practice. These results suggest that there is a great opportunity for increasing rice yield and profitability under salt-affected soils through integrated management options.

Keywords: Farmer participatory approach, management options, productivity, rice, salinity

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Effects of mixed cropping on weeds and crop yield – a meta-analysis

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Mixed cropping is one of the strategies proposed for weed control, with potential to increase crop yield. However, there is a knowledge gap about the overall effect of mixed cropping on weeds and crop yield, and the conditions during which the system is likely to deliver a win-win solution. We conducted separate meta-analyses on 446 data points (227 on weed density, 98 on weed biomass and 225 on crop yield) from 38 different papers meeting the selection criteria. Across all studies, mixed cropping strongly reduced weeds but this did not translate into increased crop yield. We tested if type of companion crop used in trials, whether trials were conducted in temperate or tropical regions and if companion crops were arranged as intercrops of companion crops moderated the effects of mixed cropping. Both weeds and crop yield were strongly affected by type of companion crop with a large reduction in weed density and an accompanying large increase in crop yield evident when desmodium was used as a companion plant against striga-weeds. Furthermore, even though companion plants that were non-legumes reduced weeds more strongly than legumes other than desmodium, in contrast to legumes, they tended to be associated with reduced crop yield. The effects of mixed cropping on weed biomass were stronger in trials conducted in tropical compared to temperate regions. Differences in results of mixed cropping with desmodium, other legumes and non-legumes suggest that additional environmental benefits of the companion crop, and the knowledge of specific weed flora are critical for creating a win-win solution in mixed cropping systems.

Keywords: Agricultural productivity, agroecology, companion cropping, intercropping, push-pull, weed biomass, weed density

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Potential of bacterial and fungal endophytes in promoting growth in finger millet genotypes, Kenya

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Finger millet (*Eleusine coracana*) is an important crop to subsistence farmers commonly grown in arid and semiarid areas. The crop is highly nutritious making it an excellent crop for infants, elderly, diabetic, AIDs patients as well as poor people who live mainly on starchy foods. In the present study, three fungal (*Trichoderma asperellum, Trichoderma hamatum* and *Purpureocillium lilacinum*) and bacteria (*Bacillus subtilis* and *Paenibacillus polymyxa*) endophytes were used to determine growth promotion potential in four genotypes of finger millet (U-15, P-224, Okhale-1 and Ikhulule) in the greenhouse. Finger millet seeds were surface sterilized with 70 % ethanol for 5 mins followed by 3 % sodium hypochlorite for 20 mins and later germinated in the lab. After six days, finger millet seeds were planted in plastic pots (18 cm diameter and 21 cm depth) filled with 3 kg of sterilised soil. Each pot was drenched with 10^6 spores ml^{-1} after two weeks and boosted with similar inoculum on the third week. Eight replicates were maintained in each finger millet variety and endophytes treatments. Plant shoot height, number of tillers and number of leaves were recorded on weekly basis while fresh & dry shoots weight, fresh and dry root weights, panicle weight and grain yield were measured after four months. *Trichoderma asperellum, Purpureocillium lilacinum* and *Paenibacillus polymyxa* increased dry yield weight in U-15 (P value=0.002), P-224 (P value=0.0001) and Okhale-1 (P value=0.018). There was no significant yield increase in Ikhulule variety (P-value=.0.425). Wet yield weight, number of tillers and shoot & root dry weight increased significantly in all finger millet genotypes apart from Ikhulule.

Keywords: Arid and semiarid areas, endophytes, finger millet, growth promotion

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Genotype by environment interactions affecting simulation of rice phenology

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Adapting rice production in sub-Saharan Africa to future challenges such as climate change and maintaining food security requires functional crop models to evaluate the potential of a production environment in combination with selected rice varieties. The backbone of such models is accurately simulating phenology across a wide spectrum of environments. Rice garden experiments were conducted at five of AfricaRice's research locations with 25 sowing dates (SD): Cotonou, Benin, 2SD; Mbe, Ivory Coast, 5SD; Ambohibary, Madagascar, 5SD; Fanaye, Senegal, 7SD; Ruvu, Tanzania, 6SD. We simulated days from sowing to flowering (DTF) for 80 varieties across all these environments using cardinal temperatures derived from three existing phenology models developed by Summerfield et al. (1992), Dingkuhn et al. (1995), and Stuerz et al. (2020). The data from this experiment showed that the relationship between development rate (DR) and mean temperature is not linear as assumed in Summerfield's model, but rather stagnates as temperature increases. We therefore developed a model (Asch-Groot Nibbelink; AGN) where this relationship was captured by fitting a second order regression ($DR=a*Tmean^2+b*Tmean+c$) and taking two tangents: one horizontal at the vertex and one sloped with tangency point where DR is half of DR at the vertex. Tbase is where DR=0 while Topt is where the two tangents intersect. Temperature sum is the inverse of the slope of the sloped tangent. When regressing residuals (simulated DTF – observed DTF) against other climatic factors such as photoperiod, radiation, vapour pressure deficit, and relative humidity (RH), we found that RH explained 38,4 % of the residuals. Therefore, AGN was adjusted to include a genotype-specific RH adjustment factor resulting in Topt increasing with increasing RH. With a slope of 0.937, an r^2 of 0.938 and RMSE of 12.3 days when regressing simulated DTF on observed DTF, AGN proofed to simulate genotype by environment effects on phenology better than the three existing rice phenology models. We suggest an RH adjustment factor for optimum temperature to be included into existing rice growth models, e.g. RIDEV and ORYZA2000.

Keywords: *Oryza sativa*, phenology, relative humidity, rice, temperature

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Speed breeding in *Urochloa humidicola*: Changes in photoperiod accelerate flowering and increase seed yield

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Urochloa humidicola is an economically important tropical forage grass that is being improved through hybridisation techniques to produce genotypes with waterlogging and spittlebug (Hemiptera: Cercopidae) resistance, high nutritional quality and superior agronomic characteristics. Empiric observations suggest that changes in photoperiod and vernalisation induce natural flowering in *U. humidicola* and, consequently, seed production. Under tropical sunlight conditions, a flowering, and therefore crossing, season occurs every 12 to 16 months. As a result, breeding cycles are long and genetic gain is reduced. Little is known about the effect that changes in photoperiod can have on flowering and seed yield in *U. humidicola*. Two trials were carried out at the CIAT experimental station in Palmira, Colombia (3°30'07.1"N 76°21'19.0"W) to determine the response of sexual parental lines to different photoperiod treatments. Two light spectra, red and white, were tested in a factorial design with six photoperiod length treatments: 12/12 hours day/night, 14/10 hs d/n, 16/8 hs d/n, 20/4 hs d/n, 23.5/0.5 hs d/n and 24/0 hs d/n in order to develop a functional tool to accelerate the *U. humidicola* breeding scheme. The first trial carried out during 2019 showed treatments "16/8 hs d/n with white light" and "24/0 hs d/n with red light" as the best to induce flowering, indicated by the increased number of spikes.m^{-1} and seeds/spike (Tukey HSD, $\alpha = 0.05$). In the second trial, a factorial design was used to test the two previous successful light/photoperiod treatments over a larger number of genotypes to evaluate the variability in flowering response. The results showed that while red light triggers a faster development of flowering, white light allows for an increase in the number of inflorescences and a higher seed yield. Once established, the optimised methodology will reduce the time between breeding crossing seasons from 12–16 to 8–12 months. The findings of the study suggest that longer photoperiods can be used as a potential speed-breeding tool in *U. humidicola* breeding programme under tropical conditions.

Keywords: Flowering, photoperiod, seed production, speed breeding, tropical forages, *Urochloa*

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Effect of *Bacillus* spp. on enzyme activity and potassium uptake in lowland rice (*Oryza sativa*) under iron toxicity

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Plant associated bacteria can positively influence the ability of lowland rice to withstand toxic concentrations of soluble iron (FeII) in the soil. This beneficial interaction, however, is dependent on the bacteria strain × rice cultivar combination.

Iron toxicity is a major constraint for irrigated rice production in large parts of Asia, West and Central Africa, Madagascar, and Brazil. While it is known that tolerant rice cultivars deploy different adaptation strategies, the underlying mechanisms are not fully understood. Deciphering the role of both epi- and endophytic bacteria in tolerance mechanisms of local, adapted rice cultivars will be essential to incorporate plant traits mediating beneficial interaction with microorganisms under iron toxic conditions into future breeding efforts and agricultural management practices.

In the present study, three lowland rice cultivars with contrasting levels of tolerance against iron toxicity, namely IR31785–58-1–2-3–3 (sensitive), Sahel 108 (tolerant includer), and Suakoko 8 (tolerant excluder) were inoculated with three *Bacillus* isolates (*B. pumilus* and *B. megaterium*) and, after one week, exposed to excess iron (1,000 ppm) for eight days. The effects of bacteria inoculation were evaluated by leaf symptom scoring and determination of dry weight. Activities of five enzymes involved in reactive oxygen scavenging (ROS) were measured in inoculated and non-inoculated plants under normal and iron toxic growth conditions. Potassium and iron content in roots, sheaths and blades of the same plants were analysed by flame photometer and spectrophotometer, respectively. Enzyme activities and potassium uptake and distribution will be related to the effects of bacteria inoculation on leaf bronzing scores and iron distribution within the plants.

Keywords: Abiotic stress, *Bacillus* spp., iron toxicity, *Oryza sativa*

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Population hybrid breeding and the use of new statistical tools for sweetpotato

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Sweetpotato is a highly heterozygous hybrid, and populations of orange-fleshed sweetpotato (OFSP) have a considerable importance for food security and health. Population hybrid breeding (PHB) has been recently introduced for sweetpotato in the Peruvian, Ugandan, and Mozambican breeding platform by the International Potato Center (CIP). In addition, the transition into PHB was accompanied by intensifying the use of more modern statistical tools for phenotypic data analysis like (generalised) linear mixed models that account for spatial trends in the field. PHB has been studied in the Peruvian breeding platform for a complete reciprocal recurrent selection (RRS) cycle in three OFSP hybrid populations (H1), for which foundation, parents, and hybrids were all evaluated simultaneously at two contrasting locations. The objectives of the study were to estimate heterosis increments and response to selection after one RRS cycle in the three populations. In each H1, the yield and selected quality traits were recorded (for details see Grüneberg et al. (2022); https://doi.org/10.3389/fpls.2022.793904). The data were analysed using modern statistical approaches using mixed models fitted with restricted maximum likelihood (REML), correcting for spatial variation in the field and allowing for heterogeneity of genetic (co)variances in the tested environments. In contrast to previous approaches this leads to unbiased (co)variance estimates and to higher heritabilities because spatial noise is removed from the genetic signal. We observed for storage root yield traits exhibited population average heterosis increments of up to 43.5 %. The storage root yield genetic gain relative to the foundation was remarkably high, ranging from 81.5 % to 132.4 %. In conclusion we argue that PHB is a tool to achieve large genetic gains in sweetpotato yield and most likely other clonally propagated crops, that allows a rapid dissemination of globally true seed that is generated from reproducible elite crosses, thus, avoiding costly and time-consuming virus cleaning of elite clones typically transferred as vegetative plantlets. The transition to more modern statistical tools at CIP was enabled by the Centre for International Migration and Development (CIM), a joint operation of GIZ and the German Federal Employment Agency, by funding the position of plant breeding statistician and resulting capacity building in statistics.

Keywords: Orange-fleshed sweetpotato, population hybrid breeding, reciprocal recurrent selection, restricted maximum likelihood, spatial analysis

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Water uptake does not drive sodium and chlorine uptake in sweet potato genotypes exposed to salt stress

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Whereas potassium is taken-up actively to the plant, sodium uptake and distribution often is driven by the transpirational volume flow in the shoots of plants grown under salinity. Thus, reducing transpiration rate is regarded as an adaptation mechanism to reduce tissue salt load. In combination with a high K uptake, plants may be able to maintain growth and are, thus, seen as salt tolerant. Little is known about these mechanisms in sweet potato. Therefore, cuttings of two sweet potato genotypes contrasting in salinity tolerance (CIP 188002.1, tolerant; CIP 189151.8, sensitive) were subjected to 0 and 50 mM NaCl root zone salinity in a hydroponic system and grown under low (40 %) and high (80 %) relative air humidity (rH) to create difference in transpiration. After 18 days of initial hydroponic growth, NaCl was added for another 33 days. Cumulative plant water loss and total ion uptake were determined and related to air humidity and genotypes. Plants subjected to low rH lost twice as much water per unit leaf area compared to high rH but the Na accumulation remained almost the same. In low rH, cumulative water loss per unit leaf area in plants subjected to 50mM salt stress was significantly increased ($p < 0.003$) in the tolerant but decreased ($p < 0.001$) in the sensitive genotype whereas no difference was found under high rH. Independent of genotype, the transpirational history of individual leaves was not correlated with their respective salt load, however, young leaves of the tolerant genotype grown under salt stress in high rH maintained more than twice the amount of K as compared to the sensitive genotype. We conclude that transpirational volume flow is not the main driving force for Na and Cl uptake and distribution within the plant. However, at least at high rH, high levels of K in young leaves may allow a larger accumulation of dry matter. The sodium distributing pattern (Na deposition in older leaves) will be discussed in view of active ion transport linked with ATP trade-offs.

Keywords: Ion uptake and salt stress, vapour pressure deficit, water uptake

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Reliability of gridded precipitation products for water management studies: a case study in the Ankavia river basin in Madagascar

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Hydrological modelling for water management in large watersheds requires accurate spatially distributed rainfall time series. In case of low coverage density of ground-based measurements, gridded precipitation products (GPP) from satellite/gauge/model-based merging products constitute an attractive alternative, the quality of which must nevertheless be assessed. The objective of this study was to evaluate at different time scales the reliability of six GPPs against a 2-year record from a network of 14 rainfall gauges located in the Ankavia catchment (Madagascar). The GPPs considered in this study are African rainfall climatology (ARC2), climate hazards groups infra-red precipitation with station data (CHIRPS), the ECMWF Reanalysis (ERA5), integrated multi-satellitE retrievals for global precipitation measurement (IMERG v06 Final), precipitation estimation from remotely sensed information using artificial neural networks- cloud classification system (PERSIANN-CCS), African rainfall estimation (RFEv2) The results suggest that IMERG ($R^2 = 0.63$, slope of linear regression a = 0.96, root mean square error RMSE = 12 mm day^{-1}, mean absolute error MAE = 5.5 mm day^{-1}) outperforms other GPPs at the daily scale, followed by RFEv2 ($R^2 = 0.41$, a = 0.94, RMSE = 15 mm day^{-1}, MAE = 6 mm day^{-1}) and ARC2 ($R^2 = 0.30$, a = 0.88, RMSE = 16 mm day^{-1}, MAE = 6.7 mm day^{-1}). All GPPs, with exception of the ERA5, overestimate the "no rain" class value (0 0.2 mm/day). ARC2, IMERG, PERSIANN, RFEv2 all underestimate rainfall occurrence in the 0.2 150 mm/day, whilst CHIRPS, ERA5 overestimate it. Only CHIRPS and PERSIANN could estimate extreme rainfall (>150 mm day^{-1}) satisfactorily. According to the critical success index (CSI) categorical statistical criteria, IMERG performs quite well in detecting rain events in the range 2 150 mm/day, whereas PERSIANN outperforms IMERG for rain events larger than 150 mm/day. Because it performs best at daily scale, only IMERG was evaluated for time scales other than daily. At the yearly and monthly time scales, the performance is good with $R^2 = 0.97$ and 0.87, respectively. At the event time scale, the probability distribution

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function PDFof rain gauge values and IMERG data show good agreement. However, at the hourly scale, the correlation between ground-based measurements and IMERG data becomes poor ($R^2 = 0.20$). Overall, IMERG products can be regarded as the most reliable precipitation source at monthly, daily and event time scale for hydrological applications in the study area, but the poor agreement at hourly time scale and the inability to detect extrem rainfall >100 mm/day may nevertheless restrict its use.

Keywords: Ankavia catchment, GIRE SAVA, GPM-IMERG, Madagascar, satellite precipitation products

Specific leaflet mineral concentrations of high-yielding oil palm progenies and their implications for K/Mg management

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In oil palm, a similar fertilisation regime can result in leaflet potassium and magnesium concentrations that vary significantly from one progeny to another. This hinders the development of standardised fertiliser recommendations for this crop, as they are usually calculated to reach optimum leaflet nutrient concentrations. We tested the hypothesis that optimum leaflet K and Mg concentrations significantly differ between different oil palm progenies. Four high-yielding oil palm progenies with contrasting leaflet K and Mg concentrations (C1, C2, and C3 of Deli × La Mé origin and C4 of Deli × Yangambi origin) were treated with combinations of three levels of KCl and $MgSO_4$, in a completely randomised split-plot factorial design with six replicates, where progenies were a sub-factor.

For a given level of KCl or $MgSO_4$, different leaflet K and Mg concentrations were found between progenies ($p < 0.0001$). Leaflet K concentration and yield response to KCl applications revealed that the four oil palm progenies have different optimum leaflet K concentrations. In our study period (5–8 YAP), progenies C1 and C3 had highest fresh fruit bunch (FFB) yields (13.62 and 16.54 t ha^{-1} year^{-1}, respectively) at K2, whereas progenies C2 and C4 showed the highest yields (14.62 and 12.39 t ha^{-1} year^{-1}, respectively) at K1.

For the first time in oil palm mineral nutrition research, our study highlighted specific optimum leaflet K and Mg concentrations for different oil palm progenies in a given environment. It paves the way for adopting K and Mg fertiliser application rates adapted to specific requirements of each type of oil palm planting material.

Keywords: Leaflet magnesium (Mg) concentration, leaflet potassium (K) concentration, nutrient diagnosis, nutrient management, oil palm, optimum leaflet mineral concentrations

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Genotype × environment effects on leaf properties and pigment composition in wheat under water deficit

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Wheat growing environments are increasingly characterised by extreme temperatures and reduced water availability. These conditions can potentially result in photooxidation of pigment-protein complexes and chloroplasts components, which will lead to decreased of photosynthesis and growth. Thus, identification of high-performing and stress resilient wheat germplasms is pivotal. Photoprotection can contribute a large share to achieving such resilience as it is the interface between efficient use of absorbed light in photosynthesis and the safe dissipation of excess light energy. However, a complete understanding of the adaptive response of the wheat photoprotection system to water deficit during crop development is missing. The purpose of this research was to identify changes in leaf hyperspectral reflectance at different crop developmental stages for the youngest fully expanded leaf and the third leaf. Thirteen wheat genotypes from the Best PT panel developed by CIMMYT, were grown in the field at CIMMYT research station in Obregon, Mexico, and exposed to two different environments: water deficit and potential yield. The water deficit environment was irrigated at sowing, 50 % emergency and at the initiation of booting, whereas the potential yield environment was irrigated at sowing, 50 % emergency and every fourteen days but reduced to nine days towards maturity. The lines were selected according to their contrasting evapotranspiration performance, estimated through canopy temperature measurements, and estimation of yield in previous water deficit experiments in the field. Using frequent sensor-based methods, we studied the temporal dynamics of spectral indexes, including NDVI, NPCI, PRI and relative chlorophyll content measured with SPAD. The lines studied showed contrasting patterns for the different physiological indexes at different growth stages. These results will be linked to canopy temperature. These findings can lead to the characterisation of the dynamics of photoprotection mechanisms in wheat, which can be incorporated into a field-based screening tool for high-throughput phenotyping.

Keywords: Photoprotection, reflectance indexes, water deficit, wheat

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Impact of drought stress on leaf pigment concentration at different leaf positions in the canopy

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Wheat productivity is being challenged by increasingly frequent water deficit periods. Under these conditions light induced damage is more likely. Thus, leaf pigments should adjust to mitigate the stress caused by water deficit on the photosynthetic machinery. The aim of this study is to evaluate the impact of water deficit on leaf pigment composition using hyperspectral reflectance and SPAD data. Measurements were taken at initiation of booting on the flag, the second and third leaves using a portable spectroradiometer and handheld SPAD-502 chlorophyll meter. Nine elite bread wheat genotypes from CIMMYT's Best PT panel tolerant to heat and drought stresses were studied in the field at CIMMYT experiment station in NW Mexico during 2021/2022 growing season under drought (D) and yield potential (YP) conditions. The D treatment was irrigated at sowing, 50 % emergency and before initiation of booting, whereas the YP treatment was irrigated at sowing, 50 % emergency and every fourteen days until late grain filling. Spectral reflectance indices related to carotenoids, chlorophyll a and chlorophyll b were used for leaf pigment estimation. Results showed significant differences for treatment effect at flag and third leaves ($p < 0.001$) for carotenoids (Car). Meanwhile chlorophyll a (chl a) showed differences in flag leaf ($p < 0.003$) under YP and differences due to genotype by environment (GxE) ($p < 0.004$), while for chlorophyll b (chl b) differences were found in flag leaf ($p < 0.01$) among treatments and GxE interaction ($p < 0.003$). Low levels of SRI for car, chl a and chl b were observed in D conditions compared to YP. SPAD showed significant differences among genotypes ($p < 0.05$) in YP, and among position in the canopy (flag, second and third leaves ($p < 0.001$). These results show that water deficit has significant effect on hyperspectral reflectance properties related to leaf pigment composition. Spectral indices genotypic variability highlights the potential of this phenotyping approach for identifying water stress tolerant wheat genotypes. Further confirmation will be established by analysis of leaf extracts using HPLC, which will demonstrate relationship between changes in pigment composition and grain yield.

Keywords: Leaf pigments, spectral reflectance indices, water deficit, wheat (*Triticum aestivum* L.)

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Development of polyploid genotypes in *Mentha spicata* using *in vitro* somatic polyploidisation

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Mentha spicata (spearmint) is a widely utilised aromatic herb belonging to the lamiaceae family. It is grown across the globe for its wide range of pharmacological uses. Traditionally, it has been used to treat various respiratory and gastrointestinal conditions. Consequently, numerous research has been done on the breeding of *Mentha* spp. using traditional methods, although very few studies have explored the scope of synthetic polyploidisation in *Mentha* spp. and none in *Mentha spicata*. Hence, the aim of the current study was to obtain polyploids of *Mentha spicata* using oryzalin via *in vitro* somatic polyploidisation. Nodal segments were cultured under *in vitro* conditions on Murashige and Skoog (MS) for 48 hours prior to oryzalin treatment. Thereafter, nodal segments were treated with three oryzalin concentrations (20, 40, and 60 μM) for 24 and 48 hours. Flow cytometry and direct chromosome counting were then used to confirm the ploidy of the treated plant. Obtained polyploids were micro-propagated and transferred to be grown under field conditions. Thereafter, morphological, anatomical, and biochemical data were collected for further statistical analysis. Oryzalin treatment yielded a total of 7 polyploids across all treatments. Oryzalin at 40 μM concentration for 48 h was found to be the most effective treatment with a polyploid induction rate of 8 %. Furthermore, obtained morphological, anatomical, and biochemical data exhibited a significant difference between triploid and hexaploid plants. For instance, the leaf area, and thickness increased by almost 50 percent, and a higher trichome density was achieved in hexaploidy plants compared to the mother triploid plant. Additionally, larger stomata size and higher chlorophyll content indicate a higher photosynthetic capacity in polyploids. The results obtained provide valuable insights into the breeding possibilities in *Mentha spicata* and related species.

Keywords: Autopolyploidy, hexaploidy, *in vitro*, *Mentha spicata*, oryzalin, polyploidisation

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Effects of water deficit and radiation intensity on leaf pigments in (sub)tropical bread wheat

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(Sub)tropical wheat production is threatened by increasing, climate change - induced frequencies and intensities of soil- and airborne water deficits. Leaves, and in particular their pigments, form the basis for assimilate accumulation in plants and, therefore, the source for yield building processes. Under intense solar radiation alone, or in combination with water deficit, leaves may adapt their pigment composition to mitigate negative impacts and maintain the integrity of the photosynthetic apparatus. However, little is known about the genetic variation in pigment composition and its potential for acclimation to stress in wheat.

To test this, 4 contrasting wheat lines from CIMMYT's Best PT panel, funded by IWYP (International Wheat Yield Partnership) and FFAR (Foundation for Food & Agriculture Research), were grown in a glasshouse at the University of Hohenheim, in 1.5 l pots containing a 50/50 (v/v) mixture of soil and commercial compost. Five-week-old plants were exposed to low VPD, targeting values of 0.7 and 0.2 kPa day and night, watering withhold for 10 days and an increased radiation intensity of 1200 μmol m^{-2} s^{-1} for 1 week. Chla fluorescence, photochemical reflectance index (PRI), and SPAD were measured on the youngest fully developed leaf and two older leaves lower on the main tiller at the beginning and at the end of treatments. Concomitantly with these measurements, leaf samples were taken and immediately frozen in liquid N_2 for further pigments analysis by HPLC. Results will be discussed in relation to: 1. Identification of differences in pigment composition among wheat lines with contrasting response to water deficit and radiation intensity; 2. association of changes in the pigment ensemble and leaf reflective properties, elicited by soilborne water deficit and radiation intensity; 3. Discuss the potential of photoprotective pigments as a selection trait for drought resilient wheat.

Keywords: HPLC, leaf pigments, radiation intensity, water deficit, wheat

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Effects of water deficit and VPD on leaf pigments in (sub)tropical bread wheat

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(Sub)tropical wheat production is threatened by increasing, climate change - induced frequencies and intensities of soil- and airborne water deficits. Leaves, and in particular their pigments, form the basis for assimilate accumulation in plants and, therefore, the source for yield building processes. Under water deficit and changes in VPD, leaves may adapt their pigment composition to mitigate negative impacts and maintain the integrity of the photosynthetic apparatus. However, little is known about the genetic variation in pigment composition and its potential for acclimation to stress in wheat.

To test this, 4 contrasting wheat lines from CIMMYT's Best PT panel, funded by IWYP (International Wheat Yield Partnership) and FFAR (Foundation for Food & Agriculture Research), were grown in a glasshouse at the University of Hohenheim, in 1.5 l pots containing a 50/50 (v/v) mixture of soil and commercial compost. Five-week-old plants were exposed to high or low VPD, targeting values of 2.3/1.9 and 0.7/0.2 kPa day/night, respectively, and watering withhold for 10 days. Chla fluorescence, photochemical reflectance index (PRI), and SPAD were measured on the youngest fully developed leaf and two older leaves lower on the main tiller at the beginning and at the end of treatments. Concomitantly with these measurements, leaf samples were taken and immediately frozen in liquid N_2 for further pigments analysis by HPLC. Results will be discussed in relation to: 1. Identification of differences in pigment composition among wheat lines with contrasting response to water deficit; 2. association of changes in the pigment ensemble and leaf reflective properties, elicited by water deficit; 3. Discuss the potential of photoprotective pigments as a selection trait for drought resilient wheat.

Keywords: HPLC, leaf pigments, VPD, water deficit, wheat

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Assessing physiological responses of *Smallanthus sonchifolius* under water deprivation

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Physiologically, drought stress (lack of precipitation) in plants brings about metabolic changes which reduce photosynthesis. The present study assessed the physiological responses of yacon under drought stress using fluorescence techniques. Yacon [*Smallanthus sonchifolius* (Poeppig Endlicher) H. Robinson, Asteraceae] is an important root crop, rich in inulin-type fructooligosaccharides that originated in the Andes.
A non-destructive physiological evaluation of the chlorophyll fluorescence and photosynthesis was undertaken to determine its response to water deprivation for 2 weeks. This ongoing study aims at assessing the drought stress response of this yacon plant. To carry out the experiment rhizomes with vegetative eyes from one octoploid (2n = 8x = 58), and one dodecaploid (2n = 12x = 87) yacon genotype was selected and precultivated under semi-controlled greenhouse conditions (natural light conditions, air temperature 20$\pm$2/15$\pm$2°C day/night, relative air humidity 65%-85 %).
Preliminary results show significant differences between the control and treated plants in all parameters tested. The dodecaploid genotype proved to have superior drought response in terms of stomatal conductance and fluorescence quantum yield when compared to the other genotype with lower ploidy. The genotype with a lower ploidy level was also not able to recover after the stress treatment. This study is imperative to decipher the strategies adopted by yacon plants in response to drought stress. It will also enable the identification of specific a yacon genotype as either drought stress escaper, avoider or tolerant. Understanding the stress response of yacon under water deprivation is imperative to further improve the breeding strategies of new resistance cultivars in tropical areas.

Keywords: Chlorophyll fluorescence, drought, photosynthesis, *Smallanthus sonchifolius*

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Seasonal GHG emissions from rice production in the Mekong delta depend on water management and varietal selection

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In Vietnam rice is produced on 7.7 million ha making Vietnam the world's 6th largest rice producer. The Mekong River Delta (MRD) comprises lowland rice with providing 55 % of all Vietnamese rice production. Lowland rice production is a source of greenhouse gases (GHG) due to emissions of methane (CH_4) and – to a lesser extent nitrous oxide (N_2O). Since rice production accounts for 15 % of the national GHG emissions, Vietnam aims at reducing GHG emissions from rice production by changing farming practices. The impact of selecting different rice varieties, however, is still poorly understood. A 2-year field experiment has been conducted in the Mekong Delta, Vietnam, in the early-year seasons of 2020 and 2021 using the closed chamber method to 1) quantify the baseline emissions of 20 selected rice varieties under typical growing conditions; 2) assess interactive impacts of varieties and two different water management practices: Continuous Flooding (CF) and Alternate Wetting and Drying (AWD); and 3) to compare these field emissions against the GHG estimates in the National Communications (IPCC Tier 2 approach). The results confirm pronounced differences between CF and AWD in terms of CH_4 emission whereas N_2O emission are generally low (< 3 % of GWP). Across all varieties, the reduction potential of AWD was above the IPCC default (45 %), ranging from 59 % and 62 % in seasons 1 and 2, respectively. Thus, in dry seasons that allow control of water tables in the fields, water management determines the magnitude of GHG; under flooded conditions i.e. in the rainy seasons, however, variety selection modulates these emissions within a range of $\pm$16 %, and can thus be regarded either as an additional measure to maximise the AWD effect during the dry season or as a mitigation option in locations or seasons where AWD is not possible.

Keywords: Alternate-wetting-and-drying, IPCC Tier 2, methane

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Accelerated rhizome forming and abscisic acid concentration in sacred lotus (*Nelumbo nucifera*) by low night water temperature

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The environmental factors, such as the temperature and photoperiods, play an important role in the dormancy stage of this tropical aquatic flower species, Sacred lotus (*Nelumbo nucifera* Gaertn.). Changes of temperature partially induced the fluctuation of endogenous phytohormone which affect plant growth and development, resulted not only poor growth but also reduced flower yields in mild winter of Thailand. To access the temperature factors, the experiment was conducted in CRD for 3 months under 3 ranges of low night temperatures (LNT) of water, i.e., ambient temperature (25°C) for being a control treatment, 20°C (LNT 20°C) and 15°C (LNT 15°C) by chilling unit. The data was collected in 2 stages, i.e., 45 days after treatments (45 DAT) and 90 DAT. Phytohormone such as abscisic acid (ABA) were investigated following each experimental period. It was found that the 20°C LNT suppressed the plant vegetative growth with less leaves number, leaf area, and leaf dry weight, while the leaf was absent when plant received 15°C LNT. Both LNTs stimulated the growth of underground part of the plant. 20°C LNT gave the higher stolon elongation, greater stolon diameter and more rhizome girdling, while the 15° LNT gave longer internode. Both LNTs induced more dry weight distribution to the stolon and higher accumulation of abscisic acid (ABA) concentration than ambient temperature in all organs (leaf, stolon, node). 20°C LNT gave higher ABA concentration in stolon part while 15°C gave higher ABA concentration in leaf and node part. The greatest accumulation of ABA was occurred in stolon part of 20°C LNT. While 15°C LNT resulted in highest ABA distributed to the node part of the plant. This finding might be beneficial information for developing sacred lotus as a cut flower for off-season production.

Keywords: Abscisic acid, *Nelumbo nucifera* Gaertn., rhizome yields, water cooling

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Inoculation of indigenous *Bradyrhizobium* strains increased soybean productivity in varying growing conditions in northeast Germany

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Soybean (*Glycine max* (L.) Merr.) is one of the world's most important oilseed and protein crops. In Europe, commercial inoculants containing exotic *Bradyrhizobium* are often used to inoculate field-grown soybeans. However, the effectiveness of these inoculants has often been low. The use of indigenous *Bradyrhizobium* is among the options to enhance biological nitrogen fixation and increase soybean grain yield. Two field studies were conducted in northern Germany in 2020 and 2021 to evaluate the symbiotic potential of indigenous *Bradyrhizobium* strains as potential inoculum. The objectives were to: 1) assess the ability of locally isolated *Bradyrhizobium* strain(s) to improve soybean productivity under rainfed and irrigated conditions; and 2) assess the effects of irrigation on nodulation, grain, and protein yields in soybean. Three *Bradyrhizobium* isolates (GMF14, GMM36, and GEM96) plus a standard strain (USDA110) and no inoculation control were tested in combination with three soybean cultivars (Siroca, Sultana, and Merlin) of varying maturity groups in a 5 × 3 factorial design. There were significant strain × irrigation interactions on nodulation, protein, and grain yields. Irrigation resulted in almost twice increase in nodule weight but slightly increased nodule number. However, there were minimal *Bradyrhizobium* effects on nodulation. Inoculation with strain GMF14 significantly increased grain and protein yields, yielding an average grain and protein yield of 2013 kg ha^{-1} and 765 kg ha^{-1}, respectively, compared to 1814 kg ha^{-1} and 718 kg ha^{-1} in the standard USDA110. While irrigation did not significantly influence crude protein content, it increased grain and protein yields by 25 % on average. Moreover, irrigation had a more pronounced effect on USDA110 than on other strains. Irrigation increased grain yield by 47 % in USDA110-inoculated soybean but only by 11 % in GMF14. Although irrigation increased grain and protein yields in all three cultivars, we saw a more pronounced effect on the cultivar Siroca than on Sultana and Merlin. The study found that supplemental irrigation and using indigenous *Bradyrhizobium* strains as inoculum are viable options for increasing soybean production in northeast Germany.

Keywords: Soybean

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Genetic integrity and diversity in *Urochloa brizantha* collection maintained in the ILRI forage genebank

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The ILRI forage genebank maintains several different species of *Brachiaria* grasses (*Urochloa* spp.) *in–situ* at its Zwai field site, Ethiopia, for over 30 years. We studied the genetic integrity in the Urochloa brizantha (syn. *B. brizantha*) collection, consisting of 252 accessions, in order to determine the integrity of plants within accessions and whether contaminants had been introduced. A total of 748 plants from 252 accessions, sampling two to three plants per plot per accession, were genotyped by the genotyping-by-sequencing (GBS) method of the DArTseq platform (Diversity Array Technology). A total of 162,002 SNP and 220,603 SilicoDArT genome-wide markers were generated. Of these, 51 % of the SNPs and 39 % of the SilicoDArTs were mapped onto the *U. ruziziensis* genome. The genetic integrity of plants within accessions was assessed based on a pairwise IBD (Identity-By-Descent) analysis using the Maximum Likelihood Estimation (MLE). Of the three plants sampled within a plot (within accession), 152 accessions (60 %) were 100 % true-to-type, indicating that there was no mix-up, mislabeling, or cross-pollination from other accessions. In 33 accessions (13 %), one of the three plants was genetically different but showed a close genetic relationship (parent-offspring, full-sib, or half-sib) to the remaining two plants, indicating some level of cross-pollination had taken place in these accessions. In another 50 accessions (20 %), one of the three plants was genetically distinct from the other two plants, while the three plants were unrelated to each other in another 17 accessions (7 %), indicating that a mix-up or potential contamination had been taken place in this group of accessions. Clustering analysis using the discriminant analysis of principal components (DAPC) and hierarchical clustering detected four to five major clusters, each with further subclusters. The results of this study provides useful information for the management and conservation of the collection in the ILRI forage genebank. The substantial genetic diversity observed in the collection reveals the potential of the collection for further genetic studies.

Keywords: *Brachiaria*, forage, genetic diversity, genetic integrity

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The not-so-royal tour: Impacts of farming on the quality of groundwater and surface water in Tanzania

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A recent film, "Tanzania: The Royal Tour", portrayed Tanzania as the cradle of humanity. The film, starred by Tanzania's President, H.E. Samia Suluhu Hassan and recorded during the COVID-19 pandemic, indicates how vastly rich the country is in terms of natural resources. What is not shown, however, is that having riches of resources is one thing but the quality of such resources is a different phenomenon altogether. Natural resources such as groundwater and surface water are vulnerable to anthropogenic activities that take place in order to feed the world. Some of the recent assessment we conducted in different places Tanzania in the past 3 – 4 years indicated that farming and other were having an additive impact on the country's water resources. For this conference, we chose to showcase five assessments conducted the Mara ecosystem, Manyara area, Zanzibar, and Kilimanjaro. In all cases, water samples were collected and analysis was performed to determine the level of various environmental pollutants. In one of the studies, we conducted in the Mara ecosystem, it was found that Pb and Hg, with mean levels of 70.29 and 17.95 μgL^{-1}, respectively, were significantly above the standards stipulated in the WHO guidelines. In another study we conducted in the same ecosystem, it was found that for samples collected during the rainy season, the Mara River water were enriched with Pb, Hg, Cr, Cd, and As (0.56, 0.03, 0.55 $\pm$ 0.03, 0.48 $\pm$ 0.03, and 0.4 $\pm$ 0.03 mg L^{-1}, respectively – maximum levels). In a study we conducted in the Manyara ecosystem in Northern Tanzania, levels of nitrate in groundwater exceeding 10 mg L^{-1} were found next to agricultural fields indicating inputs from farming activities. In conclusion, there is a need to control inputs of detrimental chemicals from farming activities into the natural environment by adopting more sustainable farming practices.

Keywords: Environmental sustainability, groundwater pollution, surface water chemistry, Tanzania, unsustainable farming practices

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Role of arbuscular mycorrhizal fungi (*Rhizophagus irregularis*) on mercury tolerance of *Medicago truncatula* in relation to mercury and zinc concentration

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Mercury (Hg) pollution of soils is a critical environmental problem. To rehabilitate Hg contaminated soils, arbuscular mycorrhizal fungi (AMF)-based phytoremediation may be supportive, yet the functional potential of AMF in response to Hg exposure is unclear. In a greenhouse experiment, we assessed the response of *Medicago truncatula* (biomass, Hg tolerance index (TI), Hg partitioning) to different Hg concentrations [0 (Hg0), 25 (Hg25), 50 (Hg50) $\mu g\ g^{-1}$] in treatments with (AM) and without (NM) inoculation of the AMF *Rhizophagus irregularis*. Additionally, zinc (Zn) uptake and the expression of two Zn transporter genes (*MtZIP2, MTZIP6*) were examined, because Hg and Zn share the same outer electronic configuration, inferring a potential competition for the same transporters. Although AM plants revealed lower biomass than NM plants, they showed a higher Hg TI. Plant roots were identified as dominant Hg reservoirs. At Hg25, *R. irregularis* decreased the Hg translocation from roots to stems, while Hg translocation was increased at Hg50. Hg in leaves originated mainly from atmospheric uptake. A lower Hg concentration in leaves of AM than NM plants was found, indicating a regulatory effect of *R. irregularis* on stomata functioning. The negative relationship between Hg and Zn concentrations in the roots of AM and NM plants implied a potential competition for the same transporters, although the expression of Zn transporters was upregulated by AMF inoculation at all Hg levels. In conclusion, this baseline study demonstrated that *R. irregularis* contributed to Hg tolerance of *M. truncatula*, suggesting the potential of *R. irregularis* for Hg-contaminated phytoremediation.

Keywords: AM fungi, heavy metals, Hg accumulations, plant-microbe interaction, root Hg uptake, Zn transporters

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The response of cassava to different fertiliser rates in two contrasting agro-ecological zones in Uganda

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Cassava is a major staple and food security crop for the rural and urban population in Uganda and an important raw material for industrial production processes. Cassava is considered to grow well on poor soils, to require no external inputs and to be grown as last crop in the rotation, so yields are usually low. To increase yields, cassava specific fertilisers are being developed and validated for different agro-ecological zones in Uganda through response, omission and validation trials. The trials were implemented in April 2021 and first results on cassava response to N, P and K are available. Cassava height was determined after 9 months of growth in 2 contrasting agro-ecological zones (Tororo, Kioga Plains; Lira North Eastern Savannah Grasslands) following application variants of 0 – 100 kg N ha^{-1}, 0 – 60 kg K ha^{-1} combined with 60 kg N ha^{-1}, 0 – 60 kg K ha^{-1} combined with 60 kg N and 15 kg P ha^{-1}, and 0 – 30 kg P ha^{-1} combined with 60 kg N and 24 kg K ha^{-1}. Cassava height was consistently increased with N, P and K application. For the N-only variant, maximum height was 2.02 m in Lira and 1.49 m in Tororo achieved at 80 and 100 kg ha^{-1}, respectively. Application of different K rates together with 15 kg P and 60 kg N ha^{-1} did not result in significant increase of cassava heights in Lira; however, a significant increase was achieved in Tororo up to 32 kg K ha^{-1} implying that K is limiting growth after N and P application. Cassava height was significantly increased with rising P application rates in Lira. In Tororo, however, no significant difference in height was observed at rates up to 15 kg P ha^{-1} and cassava heights even significantly decrease at higher rates likely attributed to other limiting nutrients. Results obtained from measuring plant height indicate that N limits cassava growth across both sites, while K limits in Tororo following N and P application and P in Lira following N and K application. However, forthcoming yield data are needed to confirm these results.

Keywords: Blend formulation, crop specific fertiliser, East Africa, *Manihot esculenta*, soil fertility

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Evaluation of wheat grain yield and soil organic carbon change under various agricultural management practices

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Sustaining soil fertility and its productivity strongly depend on the type of agricultural management that potentially can augment and maintain soil organic carbon (SOC). The aim of this study was to investigate the effect of three agricultural strategies and four crop rotation systems on the wheat grain yield and SOC changes during four growing seasons from 2018 to 2020 in Ahvaz, Iran. The main factor of the field experiment was three agricultural strategies comprised conventional (CON: mineral fertiliser, removal of all crop residues, chemical weeding control), organic (ORG: organic fertiliser, 30 % return of crop residues to the soil, mechanical weeding), and integrated agricultural strategy (IAS: mineral/organic fertiliser, 15 % return of crop residues, chemical/mechanical weeding). The subfactor was crop rotation systems, which included: fallow-wheat (F-W), corn-wheat (C-W), sesame-wheat (S-W), and mung bean-wheat (B-W). Results illustrated that wheat grain yield from the first year to the second was significantly increased for all crop rotation systems with the exception of S-W under CON in which no significant increase was observed between the two experimental years. Among agricultural strategies and crop rotation systems CON and B-W showed the highest grain yield, respectively. No statistically significant difference was observed between S-W and B-W under IAS in the second experimental year. In addition, SOC showed a remarkable increase in ORG and IAS compared to CON. In contrast to F-W, all other crop rotation systems had an incrementing effect on the content of SOC over time. Rotation of legumes with wheat and also integrated management of organic and inorganic fertilisers highly improved both grain yield and SOC. This study calls for applying wheat-legume rotations under integrated agricultural strategies for sustainable wheat production in semi-arid Iran.

Keywords: Crop residues, crop rotation, integrated management, organic

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In vitro propagation of *Capsicum annuum* L. (Chili pepper): effect of seed sterilizing chemicals, plant parts, and growth hormones on the rooting and shooting performance

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Capsicum annuum L. (Chili pepper) is an annual plant cultivated for its medicinal and food flavoring use. In Ethiopia, it is mainly cultivated in the southwestern part of the country where it represents the most important source of income for smallholder farmers. However, the crop in this area is now facing drastic problems in its seedling formation and maturation due to viral, fungal, and bacterial diseases, leading to an alarming yield decline. A way to solve this problem is by producing pathogen-free explants using *in vitro* plant propagation. This study aims at developing an efficient and reliable protocol for surface sterilisation, *in vitro* establishment, and mass propagation of aseptic cultures of chili pepper. The experiment was conducted at the Wondogenet College of Forestry and Natural resources, Ethiopia. To carry out the experiment seeds of chili pepper were obtained from the Halaba special district, southern Ethiopia. Various surface sterilisation agents at different concentrations and treatment time duration (sodium hypochlorite and/or calcium hypochlorite: 2.5–10 % and control), time: 5–15 min) were tested for *in vitro* establishment. For *in vitro* mass propagation the effects of two plant growth regulators (PGR)on rooting and shooting performance at different concentrations (IBA and BAP at 0.5–3.0 mg l^{-1}, and control in MS as basal culture media) were assessed using various *in vitro* plant parts (apical shoots and nodal segments). Throughout the experiment parameters such as lever of surface sterilisation, germination rate, shoot length, leaf number, roots, and morphological abnormalities were collected and analysed to determine what sterilisation agent and PGR are effective in the mass production of *in vitro* chili pepper. Preliminary results show that chili pepper seeds are able to germinate under *in vitro* conditions after surface sterilisation producing both roots and shoots. Further evaluation will determine the effects of the PGR on the growth and development of chili pepper for their mass propagation. The development of an efficient mass propagation protocol of aseptic chili pepper plantlets will ensure the availability of pathogen-free germplasm for Ethiopian farmers who

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are dependent on this crop for their subsistence.
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Keywords: *Capsicum annuum*, *in vitro* cultures, mass propagation, pathogen-free, plant growth regulators, surface sterilisation

Mathematical model to predict and simulate bulk tomatoes temperature stored in a nature-assisted low-cost-low-temperature storage structure for rift valley production area in Ethiopia

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Ethiopia, especially the rift valley region, produces a wide range of fruits and vegetables for the central market. Despite high production the post harvest loss due to absence of cooling room facilities is high. The use of commercially available mechanical refrigeration is expensive and cannot be afforded by local farmers. This work was conducted with the aim of developing a mathematical model and simulation to predict product temperature after employing combined use of three natures assisted cooling methods (daytime evaporative cooling (EC), nighttime ventilation (NV) and use of high thermal mass materials). A 3D time-dependent heat transfer in the moist air interface in COMSOL Multiphysics is employed to develop the model that predicts and simulates tomatoes' temperature stored in a low-cost low-temperature storage structure that combines that above cooling principles. The construction materials for the storage structure were high thermal mass materials. Simulation results indicate that, during daytime, employing an EC system for 10 hours provides a 9.65 K reduction in product temperature from an ambient temperature. Additionally, utilising the NV cooling system (when nighttime air temperature is cooler than storage room temperature) in tandem with high thermal mass materials for 8 hours enables to maintain the product temperature, assisted by the daytime EC system at around 298 K. Generally, employing EC and NV cooling systems with the assistance of high thermal mass material enables to create and maintain product temperature at least 10 K below ambient. Based upon the Q10 concept this temperature reduction could double the storage time of the fruit compared to fruits stored in ambient temperature.

Keywords: Evaporative cooling, nighttime ventilation, thermal mass, tomatoes

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Dose-dependent of melatonin and gibberellin priming improve seed germination and growth indices of *Salvia officinalis* L.

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The importance of medicinal plants is increasing day by day and their consumption is increasing as well. One of the obstacles in cultivating these plants is the low seed germination due to dormancy. Melatonin and gibberellin are the most important growth regulators which have decisive roles in the growth and development of plants. To identify an effective priming dose of these regulators on seed germination, seedling growth and dry matter of *Salvia officinalis* L. in a lab experiment, effects of ten levels of hormone priming (50, 100, 150, and 200 ppm of gibberellin and 50, 100, 150, 200, 250, and 300 mM of melatonin) along with a control in the complete random design with three replicates. Results showed that although all levels of melatonin and gibberellin priming caused increase in seedling growth indices (percentage and germination rate, seed vigour index, root and plumule length, and seedling dry weight), compared to control, their effects strongly was dose-dependent. The least and the most germination percentage belonged to control (30 %) and 300 mM melatonin (90 %) levels, respectively. Albeit, the application of melatonin priming at 100 mM had the highest seed vigour index (18.4 %) and root length (2.04 cm) due, seemingly, to low plumule length, highest increase in seedling dry weight compared to control level was obtained at 200 ppm gibberellin (3-fold) and 300 mM melatonin (2.5-fold), respectively. Findings of the present study reveal that the priming of *S. officinalis* seeds by 300 ppm of melatonin and 200 mM of gibberellin may play a crucial role in the germination and growth indices of this aromatic plant.

Keywords: Growth indices, hormone priming, seed germination, seedling dry weight, vigour index

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Impact of osmotic stress on seed germination of ornamental and invasive species

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Invasive plant species spread mainly through deliberate introductions for ornamental purposes. For this reason, a large number of ornamental species have become invasive especially in the last decades, due to the intensification of climatic changes. In the present study, 15 ornamental species were selected, some of which are already listed as worldwide aggressive invasive (*Bidens pilosa, Cortaderia selloana, Pennisetum clandestinum, Nicotiana glauca*). Others are reported as invasive only in some geographical areas, such as *Centaurea cyanus* in North America and Asia. There are no reports on the invasiveness of other species included in the study, such as *Tagetes patula* Nana, *Limonium sinuatum* and *Coreopsis tinctoria*. This study focuses on seed germination, as this is the most common mechanism of plant propagation. Germination, on the other hand, represents the bottleneck of the plant life cycle, as it is the stage most susceptible to environmental constraints, including both abiotic and biotic factors. Seeds of all species were germinated in Petri dishes on filter paper moistened with distilled water in the control treatment and with increasing concentrations of PEG 6000 (polyethylene glycol), -0.25 MPa, -0.5 MPa, -0.75 MPa, -1.0 MPa. For each species 100 seeds were placed in 4 Petri dishes per treatment. Germination was recorded daily for a period of one month. Final germination percentages were arcsine transformed and data were analysed by ANOVA. Differences between species and between treatments were significant. The most tolerant to osmotic stress were *Cortaderia selloana, Pennisetum alopecuroides* and *Pennisetum clandestinum*, and the most susceptible were *Aquilegia hybrida* and *Eschscholzia californica*. PEG germination was mainly related to the ecological requirements of the plants, those of arid areas tolerating better the osmotic stress. All invasive species showed a very high germination rate in the control and at least at some of the PEG concentrations, such as *Oenothera biennis*, which grows in humid environments and did not germinate at -1.0 MPa, but had a germination rate of more than 80 % at the other concentrations. This study helps identifying the risks of some ornamental species becoming invasive, as well as highlighting the constraints of the germination process under drought conditions.

Keywords: Germination, invasive species, ornamental species, osmotic stress

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Phenotypic variability of tartary buckwheat germplasm cultivated under the Czech Republic conditions

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Nowadays, Tartary buckwheat (*Fagopyrum tataricum* (L.) Gaertn.), a pseudocereal, grabs more attention because of its valuable nutrition, especially protein content and its suitability in a gluten-free diet, and became an alternative cereal in many countries. The characterisation and evaluation are necessary for a selection of superior genotypes that might be used in further breeding programs in local conditions. The objective of this research is to evaluate the yield, morphological traits, and protein contents from 20 genotypes of Tartary buckwheat provided by the Gene Bank of Crop Research Institute (CRI) of the Czech Republic and U.S. Department of Agriculture (USDA). The germplasm was grown under the climatic condition of the Czech Republic during 2020 and 2021. Yields and morphological traits, including plant height, branching, compactness of inflorescence, and the number of flowers were evaluated. The seed storage protein contents, including albumins, globulins, and gliadins were evaluated by Kjeldahl's method. A significant difference in yield, branching of the main stem, and protein content between each genotype from both years was observed, while the other morphological traits, including plant height, thousand seed weight, compactness of inflorescence, and the number of flowers were stable in each genotype. The average protein content in all cultivars was 13.20 $\pm$ 0.67 % of dry weight (dw) in 2020 and was decrease slightly to 10.68 $\pm$ 0.61 % of dw in 2021. In addition, the difference in the temperature and precipitation in both years was observed. Therefore, the increase in the yield and decrease in the protein content of 2021 might be caused by the warmer temperature and more precipitation in 2021. However, three genotypes, including Peremoga, Lira, and No.2316, can maintain the high yield and protein content in 2020; hence, they were suggested for cultivation in the Czech Republic and can be used in the further breeding programs. This pilot research can be used to improve the quality of Tartary buckwheat under the conditions of the Czech Republic.

Keywords: Breeding, phenotypic traits, protein content, Tartary buckwheat

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Advances in the development of localised P-dipping technique as a simultaneous solution to phosphorus overuse and sustainable lowland rice production in sub-Saharan Africa (SSA)

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A global challenge for agricultural production is to meet the needs of a growing population while addressing environmental concerns related to the overuse of fertilisers and unstable growing conditions due to climate change. At the same time, soil P deficiency and insufficient P application due to the limited purchasing capacity of smallholder farmers are major constraints for rice production in SSA. Our studies provide a practical approach to addressing these issues for smallholders' lowland rice production in SSA.

First, our pot experiments identified that: (1) a short dipping duration of rice seedlings (30 min) in P-enriched soil slurry at the optimal P concentration of 4.3%-5.0 % P_2O_5 or the P-dipping technique enhances early rice growth; (2) the P-dipping creates a soluble P hotspot around the root system, which induces vigorous surface roots and facilitates P uptake from the spot, thus increasing P use efficiency even in high P-fixing soils; (3) rice genotype with a shallow root system has a positive combination with P dipping, which significantly improves P use efficiency and initial rice growth.

Second, we conducted on-farm trials (2018–2020) to confirm the effectiveness of P-dipping in rice fields in Madagascar, where acid and P-deficient soils, typical in SSA, are widely found. Twenty-two field trials have demonstrated that P-dipping is a novel technique for increasing rice yield with improved P use efficiency in high P-fixing soils. In addition, P-dipping significantly shortens days to heading than conventional P application via broadcasting, thereby avoiding late-season low-temperature stress at high-altitude sites. Moreover, P-dipping avoids submergence stress after transplanting by accelerating initial plant growth and achieving high yields in the affected fields. Thus, this technique will be one of the major adaptation strategies for smallholder farmers to increase rice yields with little fertiliser inputs and reduce the risk of

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environmental stresses.
Third, a large-scale pilot trial (2020–2021) confirmed the significant effect of P-dipping on rice yield under a range of environmental and farmers' management practices in the central highlands of Madagascar. Currently, the practice is being disseminated to hundreds of farmers' fields to ensure sustainable rice production and improve the livelihood of farmers in SSA.
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Keywords: Cold stress, Madagascar, P-dipping, P-use efficiency, root architecture, submergence stress

Effect of hydrogel and olive mill wastewater on germination and seedling growth of cress as bioindicator

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Olive oil-producing countries are facing challenges with their wastewater management. Several studies have highlighted the potential phytotoxicity of olive mill wastewater (OMW), despite its frequent use for agriculture. As a potential solution, hydrogels, synthetic polymers capable of absorbing big quantities of water and releasing it back, have been applied as a soil amendment to increase the soil's water holding capacity. This study investigates the interaction between hydrogel, as an amendment for growing medium, and diluted OMW, as a moistening solution, as well as their combined effect on germination and seedling growth of cress (Lepidium sativum), commonly used as bioindicator. Two biodegradable Polyaspartic acid-based hydrogels, clPASP-HMD (H9) and clPASP-OH-HMD (V26), differing in their synthesis pathway and chemical structure, were developed and used in this study. Each hydrogel was blended with soil at a ratio of 0.2 % (w/w), and the blends were used as the growing media. Polyphenol-rich OMW from Spain was used as the moistening solution in concentrations of 0, 10, 25 and 40 % (v/v). The diluted OMW solutions and the hydrogel-containing growing media were tested on a germination test with cress seeds according to DIN EN 16086–2. After 72 h, the germination percentage (GP) and seedlings' root length (SRL) were recorded. The germination assay showed that GP was not affected by hydrogel addition, independent of the used OMW concentration. Similarly, no phytotoxicity effect was found at any tested OMW concentration within each of the growing media, suggesting that the dilution was efficient to reduce the potential phytotoxicity of OMW. Furthermore, SRL of the samples with hydrogel VH26 at OMW concentrations of 10 and 25 % were significantly lower ($p < 0.05$) than that of the samples with hydrogel H9, highlighting the effect of differing hydrogel properties. By applying hydrogel together with OMW, the properties i.e., swelling capacity, sensitivity towards salt in its environment, or influence on the biodegradability shall be further considered.

Keywords: phenolic compounds, phytotoxicity, polyphenols

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Phenotypic plasticity of *Anacardium occidentale* L. seedlings to salt stress based on physiological indicators

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The study of the response to salt stress from physiological indicators in genotypes of *A. occidentale*, contributes to the knowledge of the adaptive mechanisms of this species to stressful conditions. The objective of this research was to analyse the phenotypic plasticity and the variation in indicators related to photosynthesis in two genotypes (red and yellow) of *A. occidentale* during the seedling phase under controlled glasshouse conditions. The effect of five salinity levels (0.02 $dS.m^{-1}$, 5 $dS.m^{-1}$, 10 $dS.m^{-1}$, 15 $dS.m^{-1}$ and 20 $dS.m^{-1}$) on characters associated with the photosynthesis, gas exchange and the content and fluorescence of chlorophyll. The reaction norms was graphed and the phenotypic plasticity in response to salt stress of the evaluated indicators was calculated. The red variety showed the greatest effects due to saline stress in the indicators photosynthetic rate, transpiration, substomatal CO_2, Fm, Fv, Fv/Fm, Fv/fo and Pi abs. The reaction norms generally showed a sharp drop in the indicators compared to 5 $dS.m^{-1}$ and more stable in the rest of the salinity levels. The significant differences found in terms of phenotypic plasticity showed higher values in the red variety in most of the indicators evaluated. The negative effect of salinity in the seedling stage on indicators related to photosynthesis, gas exchange, content and fluorescence of chlorophyll was found, as well as the significant differences in terms of the indicators evaluated and the levels of phenotypic plasticity of the same between varieties. Photosynthesis, chlorophyll content and stomatal conductance were the indicators that showed the highest values of phenotypic plasticity.

Keywords: Cashew, plasticity, salinity

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Field evaluation of slow-release nitrogen fertilisers and real-time nitrogen management of spring maize in Nepal

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Several innovative fertilisers and application methods, along with different support tools have been developed to enhance precision in nitrogen fertilisation, but their comparative study on maize is yet to be done in Nepal. Thus, we evaluated different slow-release Nitrogen fertilisers and decision-making tools compared with the common urea on their effectiveness in economic return, nitrogen use efficiency (NUE), and grain yield of spring maize (*Zea mays* L.cv. Rampur Hybrid-10). A field trial was conducted at Dang Valley of Nepal in a Randomised complete block design with three replications and seven treatments: N omission- 0 kg N ha^{-1}, recommended dose (120 kg N ha^{-1}), N180(180 kg N ha^{-1}) and Leaf Color Chart based N management (LCC-kg N ha^{-1}), Green Seeker (GS-143 kg N ha^{-1}), Polymer-Coated Urea (PCU- 90 kg N ha^{-1}), Urea Briquette-deep placement (UDP- 90 kg N ha^{-1}). N application based on decision support tools (LCC and GS) and innovative fertilisers (UDP, PCU) yielded 17.35–45.81 % more grain yield than the recommended dose (RDF). The real-time nitrogen application through LCC and Green Seeker and slow release N fertiliser (PCU and UDP) resulted in higher agronomic efficiency of nitrogen-AEN (21.30–27.82 kg grain kg^{-1} N) compared to RDF (12.15 kg grain kg^{-1} N) and N180 (19.87 kg grain kg^{-1} N). UDP resulted in higher grain yield 5.25 t ha^{-1}), partial factor productivity of N-PFPN (58.37 kg grain kg^{-1} N), and AEN (27.82 kg grain kg^{-1} N) while reducing N dose by 25 %. Based on the economic feasibility and ease in the application, urea briquette (UDP) and Leaf Color Chart (LCC) based N application seems promising in Nepalese conditions. However, their effectiveness should be validated in diverse agroecology, soil, and climatic conditions for a general recommendation.

Keywords: decision support tools, briquette urea, green seeker, leaf colour chart, maize, nitrogen use efficiency, polymer coated urea

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Performance of nitrogen enriched compost pellets on growth of *Oryza sativa* L. in Sri Lanka

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Paddy is occupying almost 34 percent of the total cultivated area in Sri Lanka where rice is the staple food. Urea is the main Nitrogen source in paddy cultivation and Nitrogen loss is one of the major problems faced by paddy farmers in Sri Lanka. Controlling the nitrogen releasing behaviour of fertiliser is an effectual way of mitigating this problem. Compost pellets rich in Nitrogen have a high potential to reduce Nitrogen depletion and enhance crop growth performance. An experiment was conducted to evaluate the performance of rice (*Oryza sativa* L.) supplied with nitrogen-enriched compost pellets. As the nitrogen source, $(NH_4)_2SO_4$ was used instead of urea to avoid practical difficulties during pelletizing. Plant growth and yield parameters were measured to assess the effect of pelletized forms of seven different organic amendments in the combinations of 70 % Compost + 30 % Fish Tonic Based Liquid Fertiliser + Biochar; 70 % Compost + 30 % Fish Tonic Based Liquid Fertiliser; 70 % Compost + 30 % $(NH_4)_2SO_4$; 70 % Compost + 30 % Biochar and 100 % Compost in comparison with the inorganic fertiliser recommendation of Department of Agriculture (DOA) in Sri Lanka as a controller for three months rice variety (BG 300). Treatments were arranged in a Latin Square Design including four replicates in 0.675 m^3 plots. According to the SAS statistical analysis, some vegetative parameters (Plant height, number of leaves) recorded in 70 % Compost + 30 % $(NH_4)_2SO_4$ pellets treatment were significantly higher than the DOA recommended inorganic fertiliser treatment. The total yield was recorded as 1.30 kg per plot and 2.29 kg per plot in DOA recommended treatment and 70 % Compost + 30 % $(NH_4)_2SO_4$ pellet treatment respectively. The number of panicles and the total yield of these treatments suggested that, 70 % Compost + 30 % $(NH_4)_2SO_4$ pellet treatment can produce a high yield than the DOA recommended inorganic fertiliser. Production of nitrogen-enriched compost pellets by incorporating $(NH_4)_2SO_4$ could address various drawbacks related to Nitrogen loss by controlling the nitrogen releasing behaviour of fertiliser effectively.

Keywords: Biochar, nitrogen enriched compost pellets, pelletisation

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Performance of rice (*Oryza sativa* L.) plants with different traditional organic formulations in Sri Lanka

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Although inorganic fertilisers are the most popular among Sri Lankan rice farmers, several drawbacks such as destruction of beneficial microorganisms, pollution of drinking water and reduction of soil health have been reported. Therefore, compost has been recommended to apply for paddy fields as an organic fertiliser. As compost does not release all nutrients as plant requires, alternative nutrient supplements have to be used. One such alternative is the traditional organic formulations obtained from the fermentation process of different organic materials prepared with low cost input materials. A pot experiment was conducted to evaluate the effectiveness of traditional organic formulations with rice (*Oryza sativa* L.). Two rice varieties namely Bg 366 (improved variety) and Masuran (traditional variety) were used to evaluate the vegetative, reproductive and yield characteristics of rice plants. Treatments were arranged in a Randomised Completely Block Design (RCBD) with four treatments and three replicates. Compost (T1), Jeevamrutham - an Indian traditional organic formulation (T2), fish tonic (T3) and a combination of fish tonic with fish powder (T4), were tested with no fertiliser (T0) for four months. Vegetative parameters viz. number of leaves per bush, plant height, number of tillers per bush, leaf colour; reproductive parameters viz. number of panicles per bush, grains per panicle, panicle length; and yield parameters viz. thousand seed weight and yield per bush were recorded in both rice varieties. Data were analysed by analysis of variance using SAS 9.4 software. Results concluded that the yield of the compost treatment (T1) alone was significantly higher than other treatments with Bg 366 while all the other treatments were not significantly different in yield. Masuran did not show a significant difference in the yield. It was concluded that compost was better than tested traditional organic formulations, however the effect of compost+organic formulations has to be field tested.

Keywords: Fish tonic, Jeevamrutham, rice (*Oryza sativa* L.), sustainability, traditional organic formulations

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Weed control using environmentally friendly alternatives in smallholder agriculture in Cuba

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Plant residues and organic amendments have shown to have herbicidal effects under different climatic conditions. In countries like Cuba, this is particularly important because such materials are available, while herbicides usually are hardly affordable for small farmers. In addition, organic amendments as soil treatment were shown to have less environmental impacts than chemical herbicides. In order to evaluate the herbicidal effects of plant residues in comparison the manure and plastic mulch the following treatments were tested: I) air dried cabbage (*Brassica oleraceae* L.) residues at an amount of 10 Mg ha^{-1} with plastic mulch, II) poultry manure applied at an amount of 50 Mg ha^{-1} with plastic mulch, III) plastic mulch only, IV) a control without any treatments against weeds. The experiment was carried out on a Ferric Acrisol soil in the central part of Cuba with four replicates during 60 days. The taxonomic classification of the weeds, their number and weight were determined at the end of the experiment. The results showed 11 predominant species in the control treatment while the other variants had a maximum of only two species. The only treatment capable of eliminating all weeds was the application of cabbage residues with plastic mulch. The plastic mulch alone or with poultry manure could not control *Eleusine indica* and *Cyperus rotundus*, because of their vigorous reproductive structure resistant to solarisation. Furthermore, the application of manure leads to an increase of the weed´s biomass due to the nutrients applied. Especially for smallholder farms, dry cabbage residues with plastic mulch can be recommended as a cost-effective and environmentally friendly weed control measure.

Keywords: Agroecology, organic farming, weed managment

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Performance of selected *Oryza sativa* L. variety to *Trichoderma viride* with different organic soil amendments

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Rice (*Oryza sativa* L.) is the staple food crop cultivated on a large scale in Sri Lanka. Under the present context in Sri Lanka, it is a big challenge to provide the necessary nutrients for rice plants without using inorganic fertilisers. *Trichoderma viride* is a beneficial fungus that is reported to have several mechanisms to enhance plant growth. The research was conducted to evaluate the growth, development, reproductive and yield performance of rice plants grown on soil containing *Trichoderma viride* mixed with some selected organic amendments. The growth, development, reproductive, and yield parameters of rice plants were examined and recorded. Ld 253, a short duration (85 days), improved rice variety, which is cultivated island wide due to the attractive quality attributes was tested with three different biochar combinations and two different biochar application rates, viz. 500 kg ha^{-1} and 5,000 kg ha^{-1}. T1– Guinea grass (*Megathyrsus maximus*) + *Trichoderma viride*, T2– Gliricidia (*Gliricidia sepium*) biochar + *Trichoderma viride*, T3– Paddy husk biochar+ *Trichoderma viride*, T0– Control (No soil amendment+ No *Trichoderma viride*). The experiment was arranged in a randomised complete block design (RCBD) with three replicates. Plant growth and development parameters, leaf colour code, seeds per bush, and yield per bush were recorded and analysed using ANOVA. All Trichoderma viride treated organic amendments were significantly higher than the control treatment, whereas the two different application rates were not significantly different. Results concluded *Trichoderma viride* can be used as a potential growth-promoting agent in rice cultivation. *Trichoderma viride* treated biochar in 500 kg ha^{-1} application rate is recommended as an organic amendment to enhance the performance of Ld 253 rice variety due to the availability and the cost-effectiveness of guinea grass (*Megathyrsus maximus*) biochar can be suggested in Sri Lanka.

Keywords: Biochar, organic amendment, rice, *Oryza sativa*, pyrolysis, *Trichoderma viride*

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

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

Keywords: Salinity, screening tool, sweetpotato

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Effect of cowpea living mulch on soil quality and maize grain yield in northern Ghana

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Low soil fertility is a major constraint for maize production in West Africa and the use of legumes as living mulch improves soil fertility and yield of main crops. However, there is limited literature on the appropriate time to plant living mulch in maize-based cropping system in West Africa. A 2-year (2017–2018) study was conducted to determine the effect of cowpea living mulch (CPLM) on soil quality and grain yield of maize in northern Ghana. A 3 × 4 factorial treatment combination of maize maturity types and CPLM was laid-out in a randomised complete block design with 4 replications in Northern and Upper East regions of Ghana. The maize maturity types were extra-early; Abontem, early; Omankwa and medium; Obatanpa. The CPLM included control (farmer practice), CPLM with maize planted on the same day, CPLM planted at 1-week after maize and CPLM planted at 2-weeks after maize. Principal component and correlation matrix analyses were used to select minimum data set for soil quality index (SQI) calculation. The SQI for CPLM improved by 50–100 % compared with that of the farmer practice during 2017 and 2018 in both locations. The CPLM significantly increased maize grain by 34–37 % relative to the farmer practice during 2017 and 2018 in Northern Region. In Upper East Region, the grain yield for CPLM was 84 % higher ($p < 0.01$) than that of the farmer practice during 2017 but the grain yield decreased with CPLM relative to that of farmer practice during 2018. Maize maturity types affected ($p < 0.05$) grain yield during 2017 in Northern Region but did not show significant effect on grain yield during 2018 and both years in the Upper East Region. The results suggest that smallholder maize-based farmers in northern Ghana and similar agro-ecologies in West Africa can intercrop cowpea as living mulch especially at 1–2 weeks after planting maize to improve soil quality and increase maize grain yield. Depending on the calendar days of the cropping season in northern Ghana, smallholder maize farmers can plant the different maize maturity types particularly the early maturing type for better and stable yields.

Keywords: Living mulch, maize, savannah, smallholder farmers

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Multiple biotic and abiotic factors constrain tomato production in Kenya

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Tomato is widely grown in Kenya for fresh consumption and processing into value added products. Production is predominantly under open field conditions, and is severely constrained by various biotic and abiotic factors. A survey was carried out under the Kenya Climate Smart Agriculture Programme to document the major production challenges for targeting with different technologies, innovations, and management practices. Qualitative data was obtained in 2020 through Focus Group Discussions in nine sub counties spread in Kajiado, Siaya and Elgeyo Marakwet counties. Other data was by observation in tomato fields and visit to local produce markets. The findings showed that tomato production is considerably irrigated in Kajiado and more rainfed in E. Marakwet and Siaya. Pests and diseases, drought, high cost of hybrid seed, declining soil fertility and seasonal gluts are major constraints. Late blight *Phytophthora infestans*, early blight *Alternaria* solani and root knot nematode *Meloidogyne incognita* incidence was high in the different regions, powdery mildew *Leveillula taurica* and bacterial speck *Pseudomonas syringae* pv tomato were higher in Kajiado while bacterial wilt *Ralstonia solani* was higher in Siaya. Leaf miner moth *Tuta absoluta* was the most destructive insect pest, while thrips and whiteflies were present but less damaging. Large quantities of tomato fruit with pest damage was discarded at harvest or rejected in the market. Farmers relied on chemical pesticides heavily; the choice and frequency of pesticide application was not based on assessment of existing risk of attack. A large number of tomato cultivars was grown in different regions depending on consumer preference. High cost of hybrid seed has dampened uptake of new cultivars and compelled farmers to recycle seed. There is need to build the capacity of farmers to assess pest risks through surveillance and initiate effective control measures that prioritise low cost, environment friendly methods aimed at reducing pesticide use. Value addition capacity should also be developed to minimise wastage of fruits that may not be marketed directly due to pest damage.

Keywords: Diseases, hybrid seed, pesticides, pests, tomato

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Farmer's perspectives and innovations in cropping systems

Land use transformation of oasis systems in the Aïr Mountains of Niger

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Irrigated oasis agriculture in the Aïr Mountains of northern Niger is an example for integrated crop-livestock farming under very harsh agro-ecological conditions. Very little is known about these century old agro-pastoral systems in remote mountain areas within the Saharan desert. This study aims at analysing land use changes (LUCs) of two oases systems on Mont Bagzam, a massif in the South of the Aïr Mountains, as well as assessing the use of water resources. LUCs were quantified for 1955 to 2021 using GIS-based mapping of agriculture and natural vegetation based on aerial photographs, LANDSAT and Google Earth images. Questionnaires conducted with a total 40 farm households and local records about agricultural production were analysed in order to quantify changes in agricultural production patterns. The results of remotely sensed data and ground truthing from March to May 2021 indicate an increase of actively used agricultural land in the two oases from 5 ha in 1955 to 13 ha in 2003 and to 83 ha in 2021. New fields are mainly cultivated with the cash crops onion (*Allium cepa* L.), potato (*Solanum tuberosum* L.) and garlic (*Allium sativum* L.) around the old oasis centres. The construction of an unpaved road in 2017 linking the villages on Mont Bagzam to nearby marketplaces and to the regional centre of Agadez has greatly facilitated the sale of cash crops, leading to enhanced cultivation. Normalized Difference Vegetation Index (NDVI) analyses show an increase of the high density vegetation (cropland and trees) share from 0.1 % in 1994 and 2003 to 1.8 % in 2020. The moderate density vegetation (shrubs and grassland) share from 1.2 % in 1994 and 2003 has increased to 9.9 % in 2020, while there are no notable effects of changes in annual precipitation. Between 2019 and 2021 farmers in the two oases established 18 additional wells to the 17 already existing ones, all equipped with diesel pumps. Changes in soil properties and calculated ground water extraction above recharge levels indicate threats for agricultural sustainability and related livelihoods of agro-pastoral communities on Mont Bagzam.

Keywords: Agro-pastoral system, land use, natural resource extraction, oasis agriculture, time series

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Sustainable intensification of smallholder farming systems using push-pull as a template

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Push-pull technology is one of the intensification practices that has been used to increase yield and income in smallholder cereal-based production systems by controlling insect pests (fall armyworm and stemborer) and the parasitic striga weed, while improving soil health and providing fodder for crop-livestock integration. The technology is however restricted to maize and traditional cereals, and its mainly practiced on small plots. Harnessing the full potential of push-pull requires further intensification of the technology, to expand its scope and applicability in smallholder farming systems. The overarching aim of the study is to identify opportunities for further intensification of push-pull technology in western Kenya and to determine the effectiveness of identified (i.e. selected) sustainable intensification practices. Sustainable intensification practices that farmers want to integrate in push-pull systems were determined through focus group discussion (FGD) with 91 participants in 10 village level groups drawn from Siaya Kisumu and Vihiga counties and key informant interviews (KII) with 25 participants (scientists, extension officers, key farmers, civic leaders). Preliminary results of FGD and KII suggested that farmers prefer options that increase productivity and boost or diversify income and that provide firewood and fodder. To test the impact of sustainable practice integration on plant growth, striga and insect control efficiency of push-pull system, soil fertility and crop yield, test fields have been established on 15 farms (each with four treatments) in the three counties. The four treatments include (climate smart push-pull (maize + desmodium + brachiaria), push-pull +pigeon pea, maize + pigeon pea, and maize monocrop). The impact of the intensified system on soil fertility (relative to initial soil nutrient levels), crop productivity and pest pressure will be discussed.

Keywords: Cereals, desmodium, focus group discussion, intercropping, key informant interviews, push-pull system

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The effects of information transfer related to grass strips technology on farmers' preference for cropland management: Evidence from southern Ethiopia

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Despite high potential, the adoption rates of conservation technologies are relatively low in the global south. Amongst others, this is caused by information constraints, inefficiency related to information flows and farmers' resistance to accept conservation practices that are resource-demanding and competing for cropland. This study assesses farmers' preferences for cropland management using grass strips technology, which is recognised as a cost-effective approach and examines the effects of information regarding grass strips on their preferences. We conducted a plot-level discrete choice experiment in two rounds by including an information treatment in a within-subject design using survey data from southern Ethiopia. We find that farmers prefer grass strips with higher conservation potential, planting by line strips and higher amounts of biomass for animal fodder to adopt on their cropland. In addition, the result showed that information transfer increases preferences for adopting grass strips with medium conservation potential and animal feedstock regardless of plots' features. Furthermore, the effect of information on farmers' preferences is heterogeneously moderated by plot features, namely land certification and a plot's vulnerability to erosion. Specifically, it increases preferences for grass strips planting by line strips and on plots' boundary, respectively for plots more-vulnerable to erosion and non-certified plots -implying a strong preference for grass under strong tenure security mainly for conservation purposes while opting for boundary delineation under weak tenure. We find heterogeneity in preference that is correlated with farmers' risk attitudes and access to agricultural extension. Before information treatment, 85 % of sampled farmers are strong grass strips 'adopters' while 15 % of sampled farmers were grass strips 'doubters'. The provision of information switched 8 % of total sample farmers from 'technology doubter' to the class of 'technology adopter'. These finding highlights designing and implementing agricultural information dissemination systems under well-defined property rights might contribute to improving conservation technology adoption and thereby has the potential to enhance smallholders' productivity and welfare in the Global South.

Keywords: Cropland management, grass strips technology, information transfer, plot-level discrete choice experiment, preference heterogeneity, tenure security

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Tomato - harnessing of efficient vegetable and fruit production, processing and marketing systems in Ethiopia through practice based education and participatory research

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Ethiopia has good competitive advantages to become a vegetable and fruit exporter, considering its climate conditions. In addition, despite the current low level of vegetable consumption, the national market also has a large potential to flourish and sustain vegetable and fruit farming. There are several challenges affecting the performance of the fruit and vegetable value chain and contribute to the high percentage of post harvest losses, lack of technical knowledge and skills, lack of practice-oriented education and trainings of farmers and processors and lack of appropriate processing, storage and packaging facilities.
Via a survey which is done with face-to-face interviews of 400 selected vegetables and fruit farmers in three Ethiopian regions – Amhara, Sidama and Oromia, smallholder farmers' characteristics and farm practices, with special emphasis on the production, harvest and storage of perishable fruit and vegetables are mapped. Among the vegetable crops tomato, potato, onion and avocado and mango fruits have each been selected based on their consumption in the region and their economic importance. This information will serve as a foundation for education, entrepreneurial and community activities, all aiming to reduce post-harvest losses and thereby improving food and nutrition security. The project also aims to map farmers' aspirations and explore the influence of their aspirations on their choices of livelihood strategies and their resulting livelihood outcomes. In addition, a choice experiment questionnaire combined with statistical techniques, such as mixed logit and endogenous switching regression models will be used to answer the research questions and to achieve the research aims. The key outputs of the research will be assessment and characterisation of post-harvest losses for key vegetables and fruits, documentation of existing production, processing and marketing challenges and opportunities, and at least post-harvest technology gaps will be identified. Research results will be incorporated into curricula and into teaching materials of three Ethiopian universities.

Keywords: Ethiopia, food value chains, fruit and vegetable production, post-harvest losses

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Agroecological bottlenecks for home gardens to mitigate food and nutritional insecurity within Mbororo minority communities

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Home gardens are a nutrition-sensitive agricultural tool used to mitigate food and nutrition insecurity in different types of communities and settings around the world. The type of garden may vary, but one primary objective in the different settings is to increase the availability and accessibility of fresh nutrient-rich crops. Across the world, urban gardens, indoor gardens, rooftop gardens, and vertical farms make an important contribution to the supply of nutrient-rich and fresh vegetables in urban cities with land scarcity. In contrast, home gardens - which can be found in many rural communities in the global south - are still poorly structured and developmental collaborative garden projects mostly run just for a few years. This is more severe in the case of minority communities because they lack access to basic needs than other communities in the same locality. This study aims to evaluate bottlenecks that might hinder a home garden project to be effective in a minority community to increase the availability and accessibility of fresh nutrient-rich vegetables for home consumption and sale. The study uses qualitative research methods such as in-depth interviews, focus group discussions, and participatory observations to examine a home garden project within the Mbororo minority community of the North West Region of Cameroon. The results showed that over 90 % of the beneficiaries were concerned about hunger and income, not nutrition, in contrast, the project initiators were concerned about dietary diversity and nutrition. Indigenous vegetables such as "Lalo" (Jute mallow) were the least affected by irregular rains and pests. However, the seeds of these indigenous vegetables were scares because they were not commercialised. Poor soils, irregular rains, and pests, such as caterpillars, hindered the growth of all vegetables. The study concludes that the indigenous vegetables were the most adapted and preferred by the beneficiaries. Even with their limited knowledge of gardening and bottlenecks, the beneficiaries planted, harvested, sell, and increased their intake of fresh nutrient-rich vegetables. This suggests that capacity building and co-learning or co-development of good horticultural practices will increase the efficiency and effectiveness of home garden projects in minority communities.

Keywords: Horticultural practices, minority community, rural communities

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Agricultural production support and the adoption of sustainable agricultural practices – the case of Ghana

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To achieve food security – the first Sustainable Development Goal (SDG) – amid the growing population, food production in sub-Saharan Africa has to be increased through intensification programmes. But the intensive "monocultural" cropping, characterised by the use of synthetic fertilisers to replace missing nutrients, may affect negatively the agroecosystem. Sustainable agricultural practices (SAPs) are increasingly used worldwide to reduce the adverse effects of agricultural intensification and to maintain soil fertility. The challenge is how to successfully promote agricultural intensification and productivity growth under SAPs in order to increase food production. Moreover, very few studies have investigated the effect of external governmental interventions such as production support on farmers' SAP adoption behaviour. This article contributes to answering the question of whether it is possible to simultaneously increase smallholders' agricultural productivity and protect the environment by adopting sustainable agricultural practices. The main objective of this research was to evaluate the effect of Ghana's production support programme, integrated with technical advisory services and training, and other factors on farmers' SAP adoption intensity, i.e., number of SAPs adopted. A quantitative questionnaire survey was conducted in Northern Ghana with 540 respondents from December 2018 to April 2019. The findings of our Poison regression analysis show that farmers' access to production support, SAP training and extension through the support programme and farmers awareness of environmental and production risks, i.e., erosion and flood, are statistically significant drivers of farmers SAP adoption intensity. Result from the generalised propensity score matching shows that higher amount of the production support, decoupled from SAP adoption, can increase farmers' SAP adoption intensity and vice versa. Agricultural production support programmes integrated with extension and technical advisory services can enhance sustainable agriculture.

Keywords: Generalized propensity score matching, northern Ghana, production support, soil erosion, sustainable agricultural practices

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Farmers' motivation to adopt sustainable agricultural innovations in Rwanda

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Rwanda's smallholder agricultural sector faces numerous ecological obstacles which include soil degradation and poor soil fertility. The long-term climatic risks could affect the agricultural yields and food security of the rainfed agricultural dependant households. One alternative to address these challenges is to promote more sustainable production innovations amongst resource poor farmers. Therefore, it is imperative to understand the behaviour of farmers towards using sustainable agricultural practices as an adaptive strategy. Our study aimed to determine farmers' motivation to adopt sustainable agricultural innovations and identify the factors influencing their decisions. One-on-one interviews were conducted with farmers from Abakorana Murava Cooperative in Gisagara district, in the Southern province of Rwanda, using a semi-structured questionnaire. The findings indicate that farmers were strongly motivated to implement sustainable innovations to increase soil fertility (92 %), climatic adaption (86 %), increase yields, and community social responsibility. Some factors that significantly influenced the adoption of sustainable innovation include training, access to credit, cooperatives, and land ownership. Supporting research and development in sustainable technologies and providing incentives from government financial institutions to encourage adoption could ensure that conservation efforts are efficient and sustainable. Sustainable agricultural practices such as agroforestry could be adopted to reduce the effects of soil erosion brought about by the heavy rainfall experienced in the Southern province of Rwanda. Further, alley cropping and multi-purpose tree species could be adopted as a form of weed control. The government and stakeholders could support capacity building and training amongst farmers, thus, encouraging the uptake of sustainable innovations. This would, in turn, result in increased food production and, subsequently, enhanced household food security.

Keywords: Adaptation, ecological, innovations, motivation, Rwanda, smallholder

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Threats and management options of wild edible plants in semi-arid lands of Turkana county, Kenya

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Wild edible plants (WEPs) can be effective in the fight against hunger and malnutrition, however, sustainable use of WEPs is threatened by many factors. Due to the sensitivity of the topic and the difficulty to measure threats to WEPs, ethnobotanical studies often report threats as an afterthought despite the importance of sustainable use. Here we outline a participatory process to identify major threats facing WEPs and management options for sustainable use. Our methods combine Focus Group Discussions (FGDs) and preference ranking to derive the major threats and management options for WEPs. We showcase the application of these methods in the arid and semi-arid lands of agro-pastoral Turkana communities in northwestern Kenya where WEPs are particularly important for food and medicine. We held three FGDs each with 14 adults (age >= 18 years) in three community units (Nasiger, Atala Kamusio, and Lopur) with maximum socio-economic and environmental heterogeneity. Our informants included community health workers, community health volunteers, public health officers, nutritionists, chiefs/assistant chiefs, village elders, religious leaders, teachers, and other community members knowledgeable about WEPs. They listed and ranked both threats and potential management options against the threats. Preference ranking of important threats facing WEPs and management options revealed some differences across the three community units. Overall, major threats included climate change, overstocking, over-harvesting, and invasive species. Important management options included mitigation of climate change, preservation of local knowledge, selection, propagation, processing, and marketing of WEPs. Our findings could be widely applied for identifying threats and developing sustainable management options for WEPs. Further studies should evaluate the potential costs, benefits and risks of implementing management options and potential suitable habitats of the WEPs for optimising site-specific conservation.

Keywords: Agro-pastoral communities, challenges, conservation, field survey, focus group discussion, wild food plants

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Can coffee cultivation lead to food security under a changing climate? Evidence from western Honduras

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Central America is one of the most vulnerable areas to climatic variation. In recent years, national and international organisations are working together on climate smart agricultural practices to support coffee farmers in adapting to climate change. The understanding of coffee households' vulnerability to climate change is limited. Unsurprisingly, there is little scientific evidence to support the suitability of adaptation strategies for coffee households.
The objective of this research is to understand stakeholders of the value chain address the food insecurity of coffee farmers under climatic stress.
We integrated quantitative and qualitative methods to identify the main climate and non-climate stressors affecting coffee farmers, and the responses of both farmers and other value chain stakeholders to these stressors. Using a household survey with 348 coffee farmers, we quantified the relationships between poverty (Poverty Probability Index - PPI) and food security (measured through Food Insecurity Experience Scales - FIES) of farmers with climate and non-climate stressors, and household characteristics through a regression and classification analysis using gradient boosting models (GBM).
We found that the poverty index increases when households depend more on coffee income. Diversified households whose income depends less in coffee have a greater chance of being food secure. The coffee households were not confident how to ensure their food security under climate variation. While most of the climate-resilience practices provided by the coffee sector are focused on improving coffee tree resilience and soil against climate variability, these strategies unattended the food insecurity situation of the coffee farmers. Focusing efforts only on the production of a commodity such as coffee as a strategy for climate resilience not only does it undermine coffee sustainability in the medium term, but it also menaces the well-being of coffee-growing households.

Keywords: Climate resilience, coffee farmers, food security, poverty, resilience capacity

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Socio-ecological transformation of a traditional Moroccan mountain oasis

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Oasis systems in the Atlas Mountains of Morocco are ancient social-ecological systems, which have effectively coped with fragile, arid environments over thousands of years through agricultural practices that have stood the test of time. A central challenge for today's goals of sustainable development is to efficiently manage global modernisation processes while maintaining or even enhancing sustainable agricultural practices and livelihood strategies of rural populations. This study aims at analysing socio-ecological and economic changes affecting traditional oasis agriculture in Tizi N'Oucheg, 50 km southeast of Marrakech in the High Atlas Mountains of Morocco. Land use changes (LUCs) quantified by analysing Google Earth Images of 2003 and 2021 as well as drone images taken in 2022 show an increase of abandoned agricultural land and a decrease of cropland. This was particularly the case for fields of rainfed barley (*Hordeum vulgare* L.) on remote terraces. Ground truthing and the conduction of semi-structured questionnaires with 25 farmers in March and April 2022 revealed irrigation water availability, other job opportunities in urban regions and health problems of the ageing farmer population as main reasons for abandonment of agricultural land. 60 % of the surveyed households permanently living in the oasis stated non-agricultural activities to contribute > 50 % of their income. While crop production in the past was based on subsistence farming, nowadays barley and maize (*Zea mays* L.) are primarily only grown for livestock feeding. Average barley grain yields amount to 430 g m^2. Cereal yields were reported to decrease over the past 20 years. Vegetables, planted in areas where water availability is high enough, such as potato (*Solanum tuberosum* L.), bean (*Vicia faba* L.) and onion (*Allium cepa* L.) are sold to local markets, in addition to the sale of livestock. Apart from climate change, traditional crop-livestock systems suffer from out-migration, marginalisation, losses in traditional knowledge and biodiversity, while the rapidly growing lowland cities, such as Marrakech, increasingly occupy the old agricultural land with tourist infrastructure and hotels.

Keywords: Crop-livestock system, land use, oasis agriculture, rural-to-urban, traditional knowledge

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Assessment of the potential of orange-fleshed sweetpotato for food security and nutrition in the pastoral communities of Karamoja, Uganda

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As the frequency of droughts and floods increase due to climate change, there is need for communities to build resilience through adoption of crops and varieties that are not only adapted to these stressors but are also nutritious. Orange-fleshed sweetpotato (OFSP) is a rich source of provitamin A beta-carotene and has been shown to thrive in harsh climatic conditions. The crop is therefore potentially important for food and nutrition security in fragile environments where climatic shocks and hidden hunger are prevalent. This study assesses the early adoption of OFSP among the pastoral communities in Karamoja sub-region, and its potential as a home-grown solution for use in humanitarian interventions on food security and nutrition. Mixed methods approach was used, where 138 randomly sampled respondents from project areas in Moroto and Kotido were surveyed, and additional yield data collected from 39 sweetpotato plots in these districts. Descriptive statistics were generated from this data. Qualitative methods used were field observations during monitoring of field activities and stakeholder interviews of staff implementing activities in the districts. Findings from the baseline indicate that before introduction of OFSP, less than 10 % of the farmers were growing sweetpotato in the districts. There was willingness to adopt OFSP as a food security crop in the districts because of its quick maturity (3–4 months), high yields and for complementing sorghum, the main food crop in the area. Vine survival of OFSP was very high despite the prolonged dry seasons that the crop underwent after its introduction in the area. A yield of 6 t ha^{-1} was obtained, significantly above the national average of 4.2 t ha^{-1}. Households, in addition to consuming fresh OFSP roots, consumed sweetpotato leaves, an observation that was unique in Karamoja than other project areas in Uganda. The results therefore show that there are high adoption rates of OFSP in fragile environments and several options of utilising the crop. The various ways of utilisation make OFSP a very important food security and nutritious crop for fragile environments and integrating it in communities living in these environments is an efficient and cost-effective way of addressing food insecurity and malnutrition therein.

Keywords: Adoption, cost-effectiveness, fragile environments

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Growing vegetables on fallow rice fields between growing seasons : Challenges and opportunities in south-eastern Madagascar

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Achieving food security is still difficult for smallholder farmers in Madagascar. Farmers in Atsimo Atsinanana region are among the most vulnerable suffering from a lean period of six months every year. This situation is getting increasingly worse due to climate change effects, which cause delays in the rainy season. Rice fields lay fallow for several weeks between the two annual growing seasons. During this inter-season period, some farmers use their rice field to grow vegetables. These crops contribute to diets and incomes, and thus support farmers' food security. However, despite its potential, this practice is still rare among smallholder farmers in Atsimo Atsinanana. To explore the future potential of scaling inter-season horticulture in rice fields through food security interventions, this study intended to understand current adoption barriers. Our main objective was to identify both motivating and hindering factors affecting the decision to cultivate vegetables in the rice field. For this analysis, we tested four hypotheses, linking barriers to technical farm aspects, gender roles, market dynamics, and farmers' attitudes. Semi-structured individual interviews were conducted with 26 vegetable farmers using rice fields as well as 50 vegetable farmers using other plots to grow vegetables. To dissolve apparent contradictions in the interviews, gender-separated focus group discussions were carried out with 60 farmers. We found that technical barriers are the main constraint to this practice. Many rice fields are not suitable for horticulture, being at risk of flooding or located too far away from the farmers' homestead, which causes drudgery and increased theft risk. The practice is also hindered by beliefs and attitudes

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for example that the rice field is only for rice, fertilisers damage the rice field, or growing vegetables on the rice field is for non-local people. In addition of these barriers, low market demand and the far location of big markets further disincentivize farmers. Gender roles, however, do not seem to represent a barrier to this practice. Growing vegetables on rice fields during off season is an alternative to increase food security in Atsimo Atsinanana region, but many barriers need to be overcome to make the production on rice fields profitable.

Keywords: Atsimo Atsinanana, food security, Madagascar, rice fields, vegetable growing

Machinery ownership model for effective smallholder mechanised rice production in Ghana

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Rice is a major staple in Ghana and there are constant efforts to increase its production locally. As of 2020, local rice production figures were 987,000 tons, an increase of about two hundred thousand tons from 721,465 tons in 2017. This shows a very promising trend in ensuring local production of rice. However, the major rice producers are smallholder farmers whose processes are riddled with drudgery. In addition to ensuring continued production, the smallholder farmers are being introduced to conservation agriculture farming methods. Though they are gradually adopting conservation agriculture methods of production, the level of drudgery in their production still poses major problems for their agenda to increase production sustainably. This study was formulated on the premise that if smallholder rice farmers can own/access machinery easily, it will increase their productivity. As such the study aims at providing a machinery ownership model for smallholder farmers that is economically feasible and sustainable. This was done by first evaluating the level of mechanisation through a survey of 150 rice farmers in both the southern and northern sectors of the country. The field data collected from rice production centres in the northern and southern parts of Ghana showed that aside from the major issues with rice production mechanisation, only specific processes along the value chain receive attention regarding mechanisation. Based on technical specifications, the study provided the full set of equipment required to mechanise smallholder rice farming and then further developed economic models around ownership of the machinery. The net present value and cost-benefit-ratio analysis of the business models developed show that the best model is where farmer cooperatives own machinery and hire it out to members.

Keywords: Business model, conservation agriculture, economic, mechanisation, rice, sustainable

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Factors affecting farmer's decisions for delayed planting of rice and wheat in Bihar, India

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Rice and wheat crops occupy 70 % of the state's area and feed more than 80 % of the 7 million farmers in the eastern state of Bihar in India (MoSPI 2021). Overall productivity of the rice-wheat cropping system has been declining over time, thereby reducing farm incomes, and putting the state's food security at risk. Late transplanting of the monsoon crop paddy is common in the region which delays paddy harvesting and ultimately the sowing of the following winter crop wheat and is considered as a major reason for the low productivity. The study tries to identify the agro-economic and behavioural reasons for this delay in farm operations. We conduct in-person surveys of 2000 farmers across 10 districts in Bihar covering regions where the problem of delayed paddy planting is widespread. We find that it is not the lack of awareness among farmers that causes a delay, but their inability to access key inputs such as lack of cheap sources of irrigation which exposes them to the perils of erratic rainfall, increasing shortage of labour at peak periods, and lack of key agricultural equipment such as combined harvester which delays harvesting and raises the overall cost of production. We also survey 50 agriculture experts and find a huge gap between expert recommendations and farmers' adoption of technology. We use the best-worst scaling experiment and ask both farmers and experts to rank various alternatives based on their relative importance in timely wheat sowing. Solutions such as zero-tillage wheat and direct seeded rice exist which have a double dividend of consuming lesser inputs without compromising the yields and incomes. However, unlike experts who are more optimistic in the adoption of such agroecological practices, farmers consider them unviable due to rising costs and huge interdependence on practices of neighbouring plot farmers as compared to their western counterparts in Punjab and Haryana. We recommend policy options that provide cheap irrigation, improved water efficiency, and balanced fertiliser use that reduce water and soil pollution, thereby enabling farmers to utilise the full potential and increase crop productivity in the state.

Keywords: Balanced input use, Bihar, cheap irrigation, food security, late transplanting, rice-wheat

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Agroecology and plant protection

Controlling cassava brown streak disease and blocking a pandemics by pre-emptive action – experiences from the field

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Cassava brown streak disease (CBSD), a devastating virus disease of cassava in East Africa with pandemic proportions and severe impact. The viruses are spreading south- and westwards, to Zambia and DR Congo presenting a serious threat to cassava cultivation on the continent. We are studying the brown streak viruses to characterise the disease, identify resilient cassava varieties and to find loopholes in the biology of the viruses to disrupt the disease cycle, prevent further spread and devise solutions for crop management. In contrast to cassava mosaic virus disease (CMD), there is are no African varieties resistant to the viruses instead, there are varieties that become infected however a broader destruction of the roots from necrosis only becomes evident in following years, when cuttings from infected plants are taken for propagation. Planting of a healthy crop is key to management of the disease, however, pending a "formal" seed system for cassava, in epidemic zones, there are no sources of healthy planting materials and because of a shortage of planting material and neighbourhood exchange, human assisted spread is a main driver of the pandemics. From our fundamental research on the viruses, we concluded that, in contrast to CMD, virus spread by viruliferous whiteflies occurs but is not a main pathway of CBSD spread. Based on our findings, we concluded that there are ample options to manage this disease and decided to devise an intervention strategy to control CBSD aiming at eradication of the virus disease from the cassava fields. We report the results of our work in South Kivu, DR Congo, namely on the Plains de la Ruzizi an epicentre of CBSD where substantial cassava cultivation, in a main production zone of the crop, was disrupted by the disease. In 2017, we created an introduction farm (nursery) to receive materials from the laboratory in Germany, installed a cassava production and demonstration site and started to produce cassava keeping strict phytosanitary measures and monitoring. In March 2022 we harvested a highly performant crop from 1.5 ha, to provide virus-free cuttings to farmer's associations and NGO's in south and north Kivu.

Keywords: Disease managment, phytosanitary mesaures, virus-free cuttings

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Not all about resistance - conclusions from ten years of potato late blight field research in Kenya

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Late blight caused by *Phytophtora infestans* is still one of the most yield limiting factor in with potato farming in Africa. Varietal resistance and chemical control with Mancozeb and Metalxyl products are the most common tactics farmers consider. However, often smallholder farmers are not trained in the right and safe use of fungicides, causing limited protection, envoirnmental pollution and potential health issues.
In this context the International Potato Center conducted intensive research on late blight management. The research presented combines data from different field trials from multiple sites in the period from 2009 to 2018. All trials focussed on research questions in respect to late blight management.
In all trials the variety Asante was used as a check allowing for a comparison across years and sites. Disease pressure for the respective trials have been clustered into low, medium, high and very high disease pressure using the relative area under disease progress curve (RAUDPC) of Asante as reference. This allowed for the comparison across years and sites. More than 30 varieties and advanced potato clones have been included with the condition that those have been tested for more than three seasons, respectively. Other agronomic treatments included were plant nutrition level, seed quality and alternative disease treatments with less harmful phosphonate fungicides.
The results clearly show that the resistance level of varieties became more important at high disease pressure. However, resistance levels alone didn't explain the yield-loss relationship. Early maturing moderately resistant varieties had less yield loss than late maturing resistant varieties. Hence, the combination of earliness and resistance caused the least yield loss.
The disease control with phosphonate varied significantly between the products, the best product however achieved similar control and yield levels as the standard chemical fungicides. Therefore, phoshonates can be considered as an environmentally safe alternative.

Keywords: Host plant resistance, Kenya, phosphonates, potato late blight

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Genetic gain for resistance to spittlebugs (Hemiptera: Cercopidae) in the interspecific *Urochloa* CIAT breeding program

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Grasses from the genus *Urochloa* are sown worldwide throughout the tropics and subtropics. *Urochloa* grasses have different attributes that make them an important forage resource, however susceptibility to abiotic and biotic stresses are also common. In order to develop a superior forage source, the interspecific *Urochloa* breeding programme was started at CIAT in the late 1980's combining desirable attributes of the three most important species signalgrass (*U. decumbens*), palisadegrass (*U. brizantha*) and ruzigrass (*U. ruziziensis*). One of the main targets of the breeding programme is to continuously improve resistance to spittlebugs (Hemiptera: Cercopidae), which cause high economic damage in livestock systems throughout tropical and subtropical America. In the recurrent selection breeding scheme, seven successive cycles of selection of the apomictic hybrids and the parental sexual lines were screened for resistance to four species at the nymphal stage, measured as damage to plants based on visual scoring (0–5), using a high throughput methodology in the greenhouse. A means to measure the response to selection of a breeding programme is to estimate the rate of genetic gain for the target traits. The assembly of historical data from founders of the breeding programme and seven generations of the synthetic population of female parents in a linear mixed model, allowed the quantification of the rate of genetic gain for the improvement in resistance to spittlebugs. This rate was estimated as the slope of the line obtained by plotting the values of resistance across generations. The analysis shows a rapid and simultaneous increase in the resistance against three species of spittlebug nymphs: *Aenolamia varia, A. reducta* and *Zulia carbonaria* after seven cycles of selection. Resistance to *Prosapia simulans* was screened in only one cycle showing some level of resistance in the genotypes that can be exploited for improvement in the future. The success in the continuous improvement for spittlebug resistance can be explained by the fact that within a breeding cycle, parents are screened and selected based on their resistance level to spittlebug as part of the parental population improvement.

Keywords: Forage breeding, genetic gain, spittlebug resistance

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Species of the *Diaporthe*/*Phomopsis* complex (DPC) in European soybean and establishment of quadruplex real-time PCR for diagnosis

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Phomopsis seed decay is known as one of the most destructive soybean diseases, affecting seed quality and causing massive yield losses worldwide. The disease is caused primarily by *Diaporthe longicolla* along with other DPC species. Precise identification of the species of this complex is necessary for understanding the epidemiology of the disease and for optimal control. Based on the isolation of 32 DPC strains from DPC-damaged European soybean seeds we identified four species: *D. longicolla, D. caulivora, D. eres* and *D. novem*. These four species can be considered the principal DPC species on soybean in Central Europe. We now aim to develop a fast and accurate method to detect these pathogens via quadruplex Real-Time PCR. Based on sequences of translation elongation factor 1-alpha (*TEF1*), four specific TaqMan primer-probe sets were designed and tested for specificity and efficiency using DNA from pure cultures of these species and other important soybean pathogens from the genera *Sclerotinia, Colletotrichum, Fusarium, Uromyces*, and *Phakopsora*. Our primer-probe sets allow excellent discrimination of the different DPC species and can be used to detect and distinguish them in parallel using quadruplex real-time PCR. The quadruplex assay was tested on different plant material including healthy and infected soybean seeds or seed coats, soybean stems, and leaves. Moreover, the quadruplex real-time PCR was adapted to quantify these pathogens relative to the amount of plant material. Standard curves were created from serial dilutions of genomic DNA from each of the pathogens and from soybean plants. To quantify the amount of fungal DNA (ng) per plant DNA (ng) with the help of the standard curves, DNA samples from six soybean seed lots were tested in the quadruplex real-time PCR and SYBR Green-based Real-Time PCR assays. The results indicated that the amount of fungal biomass seems to be highly variable between individual seeds. We now want to deveolop the assay into a standard procedure for testing soybean seeds, plant material, and soil, and are planning comprehensive sampling to study the epidemiology of DPC species in Germany and testing different soybean cultivars for their resistance against the different DPC species.

Keywords: *Diaporthe* spp., European soybeans, quadruplex real-time (q)PCR

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Abundance and diversity of athropodes in chili plant ecosystems cultivated by IPM

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Chili (*Capsicum* sp.) is a strategic commodity with high economic value in Indonesia. Chili cultivation cannot be separated from the agrochemical inputs. Pest control on chili plants generally uses synthetic chemical insecticides which can reduce the diversity of arthropods. Reduced diversity of food sources for natural enemies can spur an increase in pest populations to the detriment.

The objectives of this study were to determine the abundance and diversity of arthropods in the chili plant ecosystem using IPM techniques. The observation area is 6 acres. Sampling was carried out in August-October 2020 in Jagaraga Village, West Lombok District, Indonesia, on chili fields using the IPM technique, namely a combination of the use of pheromone and botanical insecticides and non IPMl cultivation techniques using chemical insecticides, and carried out using the Yellow Pan Trap and Pitfall Trap. Observations were conducted on the generative phase of chili planting.

Result of research indicates that 612 ground surface arthropods were recorded in chili plots using the IPM system representing 41 species, 24 families and 10 orders. The order Collembola which acts as a decomposer is the most abundant (42.81 %) of the total collected arthropods collected, followed by Hymenoptera (28.92 %), and Diplopoda (12.25 %).Analysis of functional groups showed that the species richness of arthropods in IPM plots was higher than that of non-IPM. On IPM plot, there are almost all functional groups, namely predators (18 species), decomposers (11 species), parasitoids (1) species and pest 11 species. The high number of predator species in IPM chili fields indicates the large number of niches are available and the abundance of prey for predators to colonize. The Order hymenoptera is the most abundant predator group collected from the chili field IPM system. The Shanon index value of arthropods on IPM plot of 2,887 indicates that the chili ecosystem with IPM is a fairly stable habitat, the natural control mechanism is going well. Every agronomic action carried out should be able to preserve and increase the carrying capacity of the environment so that it can support the development of organisms for sustainable stability.

Keywords: Arthropods, chili plant, diversity, ecosystem, IPM

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The fascinating arthropod pest in apple (*Malus demestica*) fruit gardens: a review

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Apples (*Malus domestica*), is one most important fruit tree crops cultivated in temperate regions and newly introduced in Uganda for income and nutritional importance. However, apples are known to be susceptible to arthropod pests, known to cause damages on both the plant and fruits. To tropical researchers and other stakeholders including apple growers in Uganda, arthropod pests that damage apple are unknown. In this paper, systematic information on arthropod pests that damage apple fruit trees has been analysed. Here, recent literature on arthropod pests damaging *M. domestica* trees and their preferred host varieties under different farming systems in apple growing regions of the world have been assessed. The review focused on classifying common arthropod pests, preferred varieties and their distribution. This was achieved by using the ISI Web of Science bibliographic database and using the search terms apple entomofauna and arthropod pests in apples with keywords [apple*] AND [arthropods*] AND [pest]. It was found that, arthropod pests that damage apples belong to several groups of invasive pests which include Coleoptera and Polydrusus (beetles, weevils), Diptera (leaf, seed, fruit flies), Hemiptera (aphids, psyllids, bugs and scales), Hymenoptera (sawflies, wasps ants, bees), Thysanoptera (thrips), Trombidiformes (mites) and Lepidoptera (moths and butterflies) that attack different parts of an apple tree (leaves, fruits, stems and roots). This review endeavoured to piece together the known information about the arthropod pests that attack apples in relation to host varieties in different geographical locations. But little to none work about arthropod pests in apples of Uganda could be found. This calls for an immediate detailed study in the same. Because, for the last 10 or so years, Uganda has been growing apples yet the industry is not growing quickly due to many problems including arthropod pests that are still unknown.

Keywords: Apple varieties and geographical locations, apples, arthropods pests, distribution

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Biological control of southern blight (*Sclerotium rolfsii* L.) on beans (*Phaseolus vulgaris* L.) with *Trichoderma harzianum* R. and three bio-preparations as a soil amendment and seed treatment

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This research was conducted in the laboratory and greenhouse of the Department of Plant Protection of the Faculty of Agricultural Sciences of the University of El Salvador, during the months of March to May 2017. The effectiveness of three bio-preparations (lombriabono, bokashi, and mountain microorganisms), an antagonist *Trichoderma harzianum* (Excalibur Gold®), a relative control (Copper Hydroxide, (Kocide WG®), and absolute control (no treatment); and two methods of application (soil amendment and seed pelleting), against the pathogenic fungus *Sclerotium rolfsii* L., which causes southern blight disease in beans. The assay was conducted under greenhouse conditions with 11 treatments and 5 repetitions, plus a duplicate of the assay. The observations were carried out from planting to the first month, which is the critical stage of infection by the pathogen, inoculating the pathogenic fungus in the sterile substrate, taking emergency data 5 days after planting the bean, and then every 3 days to measure the level of infection. The data collection was done by the presence of signs of the pathogen and symptoms of the disease, the emergence, and infection in seed, and plant infection was evaluated.

The methods of application had an influence on the control of infection by *Sclerotium rolfsii* in seed ($\chi 1=93.96\,\%$ $P=2.2\times10^{-16}$). Where the lowest percentage of probability was obtained by soil amendment (2.5 %, EE=0.60), demonstrating that this practice reduces the effects of the pathogen on bean seeds. The evaluation for the application only of the products, showed differences for the infection to the seed ($\chi 4=62.52$, $P<8.55\times10^{13}$) for which it can be concluded that the treatments with biological products do influence the behaviour and development of the pathogen since the existing microbial activity can inhibit or potentiate the development of infections. For the interaction of the products only as pelleted to the seed was *T. harzianum* which presented a lower percentage of infection in the seed (4.5 % EE=3.2 %). There were strong effects of interaction between products and forms of application, for emergencies ($\chi 4=48.921$ $P=6.066\times10^{10}$), infection in seed ($X4=32.894$ $P=1.256\times10^{6}$), and plant infection ($\chi 4=15.6784$ $P=0.00348$).

Keywords: *Phaseolus vulgaris*, *Sclerotium rolfsii*, *Trichoderma harzianum*

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Assessment of preferred pest control method among cowpea farmers in Guinea-Savannah agro-ecological zone, Nigeria

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Cowpea is a major crop consumed by households in Nigeria and sub-Sahara Africa but pest threatens production at economic threshold in both quality and quantity terms. Farmers made frantic and professional efforts to check the menace using different methods but in some cases used combined control method in order to increase cowpea output. The study assessed the preferred pest control methods adopted by cowpea farmers in the guinea-savannah agro-ecological zone of Nigeria. A total of 155 respondents were selected using well-structured copies of well-structured and pre-tested copies of questionnaire and multistage sampling procedure. Result of socioeconomic characteristics of the respondents revealed the average age (46.5 years), farming experience (27.3 years), household size (9 members), extension contacts (6 times) and annual revenue (N 655, 154) among others. Input and pest statistics revealed mean values of pest control cost (N 15, 290), seed used (47.6 kg), agrochemicals (9.8 litres) and number of pests species/farm (2). Multinomial results revealed that the chemical method with reference to the manual method indicated a reduction in the use of chemical method as caused by cooperative membership ($p < 0.01$), marital status($p < 0.05$) and sex ($p < 0.05$) while the use of both methods(manual and chemical) with reference to manual method indicated that cooperative($p < 0.05$) decreased the use of both methods. High pest incidence was ranked first by cowpea farmers among all highlighted constraints to cowpea in the study area based on the result of Likert scale rating index, while specifically, sucking pod insect was rated highest among the pests attacking cowpea generally on cowpea farms. Hypothesis tested on the relationship between quantity of cowpea output and pest management method was significant at 1 % indicating that there is a significant relationship between adopted pest control method and cowpea output among farmers. It was recommended among others that farmers should be exposed to more extension education and also encouraged on cooperative membership for sufficient education on pest control.

Keywords: Control method, cowpea, Guinea Savannah, multinomial logit

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Pest control through cropping systems and biopesticides uses for sustainable farming

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In West Africa, pest pressure is one of the causes of low cowpea productivity. Controlling these constraints by using biopesticides, can be one of the alternatives to increase cowpea productivity while preserving the environment; hence, the present theme. The aim was to determine biopesticides effects on cowpea yield and pests under different cropping systems. Trial was conducted at Sotuba research station. Three cowpea genotypes (Sangaraka, Djiguifa and Ghana shoba) and a sorghum genotype (Tiandougou coura) were put under deux cropping systems with four biopesticide treatments (No treatment, neem leaves, *Carapa procera* oil, Zarama plant and one chemical pesticide K_optimal). A split-split-plot design in three replications were used. The first factor was cropping system (2 levels), the second factor was cowpea genotype (3 levels) and the third factor was biopesticide treatment (5). The plot size was 5 m long of 8 lines (30 m^2). The space between lines was 0.75m × 0.50 m for sorghum and 0.75 m × 1 m for cowpea. Organic manure (Profeba) was applied at the rate of 1 t ha^{-1} and 45 kg ha^{-1} of complex cereal (17–17–17) fifteen and forty-five days after sowing respectively. Two treatments were done in each two weeks, starting after the observation of ten (10) Aphis colonies. Data were collected on the number of Aphis colonies, grain and biomass yields. The results showed that the number of insect populations is generally higher in sole cowpea than in intercropping, this demonstrates the positive effect of intercropping for pest control. The numbers of insect decrease generally as the biopesticides treatments progresses. For average grain yield, the chemical pesticide K-optimal gave the highest yield (575 kg ha^{-1}) followed by two biopesticides neem (423 kg ha^{-1}) and *Carapa procera* (369 kg ha^{-1}) independent of cropping systems. For average biomass yield, neem recorded the highest value in intercropping system and sole cropping system respectively with Sangaraka (2028 kg ha^{-1}) and Ghana shoba (1475 kg ha^{-1}).

Keywords: Biopesticides, cropping systems, pest

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The combinations of entomopathogenic nematodes and entomopathogenic fungus for control melon fruit fly *Zeugodacus cucurbitae* (Coquillett) (Diptera: Tephritidae) in Thailand

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The use of synthetic insecticides against melon fruit fly (*Zeugodacus cucurbitae*) has been the most popular practice among farmers, however, these insecticides can not reach and kill all potential threats, as the last instar larvae and pupae live underground, resulting in less mortality effectiveness. The purpose of this study, therefore, was to investigate the possibility of combining the use of two natural enemies entomopathogenic nematodes (EPNs) 4 species: *Steinernema carpocapsae* (Weiser), *S. siamkayai* (Stock, Somsook and Reid), *Heterorhabditis indica* (Poinar, Karunakar and David), *H. bacteriophora* (Poinar) and entomopathogenic fungus (EPF) *Metarhizium anisopliae* (Metchnikoff) Sorokin isolate PSUM02. We tested seven EPNs concentrations: distilled water (control), 1,000, 5,000, 10,000, 15,000, 20,000 and 25,000 dauer juvenile (DJ) /host and five EPF concentrations: distilled water (control), 1×10^5, 1×10^6, 1×10^7 and 1×10^8 spores ml^{-1}. The effects of each EPN species and concentrations showed that *S. carpocapsae* at 25,000 DJs/host presented the highest mortality rate among all species; last instar larvae (97.50 %) and pupae (95.00 %), respectively. *M. anisopliae* PSUM02 ($1{\times}10^8$spores ml^{-1}) produced relatively low mortalities in both the last instar larvae and pupae at rates of 61.25 % and 59.38 %, respectively. In summation, the combined efforts of EPNs and EPF terminated both the last instar larvae and pupae up to 100.00 and 85.00 %, respectively; whereas the nematode alone recorded death rates of 87.50 % and 80.00 %, respectively. We anticipate that the results of this study can be used as a guideline for the selection of the most appropriate combination of both entomopathogens and concentration for more effective control of the melon fruit fly.

Keywords: Biological control, entomopathogenic nematodes, melon fruit fly, *Metarhizium anisopliae*, *Zeugodacus cucurbitae*

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Governance challenges of pesticide supply in Zambia

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Pesticide use is rising rapidly in many sub-Saharan countries, due to the availability of cheap and effective generic products, a trend coined as "pesticide revolution". Yet, pesticides are highly contested because in absence of appropriate regulatory frameworks serious human health and environmental trade-offs may arise. Drawing on a conceptual framework based on concepts of New Institutional Economics, the paper explores challenges affecting private, public, and third-sector governance across the pesticide life cycle, ranging from legislation, registration, importation, retail, use, disposal, to food markets. The analysis is based on empirical data from 76 qualitative interviews with experts, representing key stakeholders of pesticide governance such as agrodealers, importers, regulatory agencies, ministries, NGOs, universities and extension services. 13 interviews with key informants were complemented through creation of participatory stakeholder maps (Net-Maps). Expert interviews provided data for the analysis of governance challenges along the pesticide life cycle. Additionally, 18 focus group discussions and participatory impact diagrams were conducted with 159 farmers about pesticide impacts and challenges at farm level. The results reveal that farmers overwhelmingly appreciate the benefits of pesticides, but governance challenges were found on all stages of the pesticide life cycle. Information asymmetry incentivizes the private sector to sell sub-standard products and conceal risks. A lax legislation combined with weak enforcement, training and monitoring systems due to state failures and high transaction costs create an institutional vacuum in which, due to imperfect information and externalities, farmers deploy hazardous pesticides indiscriminately, with negative effects for human and environmental health. The civil society largely lacks awareness and capacities to keep the private and public sector accountable. Unaddressed governance failures may not only deteriorate the net-benefit of pesticides, rendering them demerit goods, but also undermine acceptance of agricultural intensification in general. The paper concludes with policy recommendations such as decentralisation, regional harmonisation, formalized training schemes and hybrid governance so to harness the potentials while mitigating the human health and environmental hazards of pesticides confronted by Zambia as well as other countries experiencing a "pesticide revolution".

Keywords: Governance, input markets, pesticides, sustainable intensification, Zambia

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Management of invasive american weed *Parthenium hysterophorus* could prevent the spread of mosquito-borne diseases

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Invasive alien plants have threatened the integrity of ecosystems throughout the world. They affect not only the species diversity of native ecosystems, but also threaten their biological integrity due to the increase in the movement of people and goods around the world. The number of species being introduced into new areas is rising. The spread of invasive plant species is currently a major problem in Kenya, where indigenous flora is replaced by dwellings. These species reduce agricultural yields, irrigated croplands, grazing areas, water availabilities, and contribute to the spread of vector-borne diseases. Invasive plant-like *Parthenium* can affect the spread of insect-borne diseases by limiting or amplifying the spatiotemporal distribution of vectors, pathogens, and hosts, which can, in turn, lead to the creation of infection. The aim of this study is to compare the diversity (richness and abundance) of mosquitoes in different sites in Baringo region in Kenya with special reference to *Parthenium* plant. *Parthenium* is considered one of the world's most serious invasive plants that is able to thrive and spread aggressively outside their original geographical areas. Mosquitoes Samples were collected using a combination of different trapping techniques from six sites: Longwan, Lororo, Ilgarua, Perkrra, Sandi, and Salabani. Three sites with *Parthenium* and three without *Parthenium* traps were set on different farms, and captures were made between (06:00–18:00). A total of 50.000 mosquitoes were captured and 48 species were identified. The survey was conducted to assess mosquito abundance and diversity in selected areas. This knowledge could be helpful for targeted control. By the end of this project, we expect to have an inventory of the mosquito population composition and of the abundance and richness of arboviruses. We will further gain insight into how changes in community ecology interact with the main types of land-use change and influence the dynamics of relevant arboviruses in Kenya.

Keywords: Agricultural intensification, arboviral disease vectors, invasive plants, land-use changes, mosquito ecology, *Parthenium hysterophorus*

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Effects of horizontal distance and moisture content on the infectious ability of indigenous entomopathogenic nematodes, *Steinernema hermaphroditum* EPNKU60 and *Heterorhabditis indica* EPNKU82 collected from Thailand

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Entomopathogenic nematodes (EPNs) in the genera *Steinernema* and *Heterorhabditis*, and their symbiotic bacteria (*Xenorhabdus* spp. and *Photorhabdus* spp., respectively) are lethal endoparasites of soil-borne insects. They have been used to control a wide variety of insect pests throughout the world. However, nematode ecology typically affects the ability of nematode infection. The purpose of this study is to determine the effect of horizontal distance and moisture content on the infectious potential of two indigenous EPNs from Thailand, *S. hermaphroditum* EPNKU60 and *H. indica* EPNKU82. We evaluated the horizontal movement of the two EPNs at a rate of 25 infective juveniles (IJs)/cm^2 at distances of 0, 5, 10, and 15 cm from the insect host. The results showed that S. hermaphroditum EPNKU60 and H. indica EPNKU82 killed more than 80 % of fifth instar larvae of *Galleria mellonella* L. three days after exposure and increased to 100 % five days after exposure. In one to two days, the two EPNs move horizontally up to 15 cm. The numbers of S. hermaphroditum EPNKU60 and H. indica EPNKU82 were found in the insect cadaver in populations of 24–35 and 18–34 individuals, respectively. In addition, the efficacy of the two EPNs were evaluated at different moisture contents of 0, 10, 20 and 30 % when the two EPNs were applied at 15 cm away from the insect host. Seven days after exposure, the two EPNs were still moving and successfully infecting the insect host at rates of 40–60 % and 86.66–100 % for moisture contents of 20 and 30 %, respectively. The two EPNs were found in the insect cadaver in populations of 2–4 individuals. Infectivity was not detected in treatments with moisture contents of 0 and 10 %. This study presents the information ecology for the potential use of the two EPNs as bio-agents against larvae of soil-borne insects.

Keywords: Insect pathogen, nematode ecology, soil-borne insect, wax moth

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Phytonematodes are a real concern for horticultural productivity in Ethiopia

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Food security remains the national priority in the Ethiopian agricultural development. Despite the diverse and conducive agro-ecological conditions for potential production of horticultural crops, the quantity and quality of yield remains low ascribed to several reasons of which pest damage being of particular issue. However, nematodes as a pest are commonly either overlooked or misdiagnosed. Equally important is that expertise in the area is most lacking in that much effort is needed to attract young professionals to join the field of nematology. Otherwise, the existing gap in the awareness of crop damage due to nematodes will remain animated. Accordingly, strong capacity building in human resource was essential to addressing this challenge in the long term, which is now imitated. Started in 2016, a nematological survey has been ongoing in the southwest part of the country in which the damage of plant-parasitic nematodes to most open field grown crops is severe. Tomato, potato, pepper, carrot, roses, hypericum, enset, lavandula, beetroot, coffee, green beans, and landscape ornamentals have been found infected with one or more of the economically important nematodes. In this, the current state of crop damage by plant parasitic nematodes to various horticultural crops has been mapped and a measure undertaken in nematology capacity building in Ethiopia is also shown. Moreover, following the detection of diverse nematode groups considered as a deadly pest to major horticultural crops, some were isolated, purified, identified and multiplied for subsequent greenhouse trials. Subsequently, our modelling results indicated that the current distribution and density of particularly *Meloidogyne incognita, M. javanica, M. arenaria* in the field together with the global climate change may turn out in a total crop ravage unless sustainable management options are duly taken.

Keywords: Capacity building, damage modelling, horticulture, nematode management

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Effect of aqueous extract of Hanzal (*Citrullus coloynthis* L.) Senemeka (*Senna alexandrina* Mill) and ummjelajel (*Aristolochia bracteolate* L.) on the leaf miners (*Liriomyza* spp.) on the snake melon crop

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Due to ecological imbalance and hazards caused by insecticides use, plant products or plant extracts are suitable alternatives to pesticides. This study was conducted at the Agricultural Research Corporation Farm, Gezira, in Wad Medani, Sudan, during two seasons in order to evaluate the effect of the water extracts Hanzal (*Citrullus coloynthis* L.), Ummjelajel (*Aristolochia bracteolate* L.) and Sennameka (*Senna alexandrina* Mill) on vegetable leaf miners (*Liriomyza* spp.) infesting snake melon. It is one of the most important vegetable crops grown in Sudan and an important food crop.The three plants used as water extracts grow widely in different parts of Sudan and are believed to have a insecticidal activity on many harmful insects. A randomized complete block design (RCBD) with 4 treatments and 4 replications was used. Snake melon plots were sprayed weekly with the water extracts of Hanzal, Sennameka or Ummjelajel at 10 % concentration (w/v) and a control was sprayed with water containing molasses and gum Arabic. The infestation percentage on leaves and mean number of active mines were counted twice weekly. The aqueous extracts of Hanzal, Sannemeka and Ummjelajel reduced the infestation and number of active mines significantly as compared to the control. No significant differences were found between Hanzal, Sannameka and Ummjelajel. Hanzal had a lower mean percentage of leaf infestation followed by Sannameka and Ummjelajel (season one). Hanzal recorded a lower number of active mines in season two followed by Sannemeka. Also Hanzal recorded the least number of active mines compared to Sannameka in season two. From this study it is recommended to use Hanzal at 10 % w/v for control of leaf miner species on snake melon crop. The result of the study is believed to be a good contribution in integrated pest management on vegetables in Sudan

Keywords: Aqueous extract, *Citrullus coloynthis*, *Aristolochia*, leaf miners, *Senna alexandrina*, snake melon crop

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Effectiveness of agroecological practices in controlling *Ralstonia solanacearum* wilt on solanaceous crops: a meta-analysis

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Bacterial wilt caused by *Ralstonia solanacearum* is one of most important and devastating diseases in solanaceous crop production. Various agroecological practices have been widely promoted in order to control this vascular bacterium. But how effective are these practices? A quantitative review was therefore conducted based on all publications which report agroecological bacterial wilt management practices under on-station or on-farm conditions in Scopus, Web of Knowledge and Google scholar electronic library without geographical restriction. After applying inclusion and exclusion criteria, 48 papers were retained, leading to 670 observations. The effectiveness of agroecological bacterial wilt management practices was evaluated through bacterial wilt incidence and crop yield, with a control treatment as reference. Effect size was calculated as the natural logarithm of the response ratio, and confidence intervals were determined by bootstrapping using the OpenMee software. Funnel plot and fill and trim analysis confirmed the absence of publication bias. Varietal control (n=420), integrated pest management method (n=84) and biological control (n=73) are the most studied agroecological practices, both under on-station and on-farm conditions. All agroecological management strategies significantly reduced bacterial wilt incidence and increased yields when compared to the untreated control. However, the results revealed that grafting of susceptible varieties on resistant rootstock (-4.832; n=41; CI_95%: -5.498; -4.037) was the most effective agroecological practice for bacterial wilt management in solanaceous crops, followed by varietal and biological control method. As expected, susceptible (-1.690; n=315; CI_95%: -1,967; -1.414) varieties show a higher bacterial wilt incidence (+142 %) compared to tolerant varieties (-2.659; n=83; CI_95%: -3.178; -2.140), but yields were not significantly different. Overall, agroecological practices appear more effective in humid zones than in arid zones, and more effective in highly acidic soils than in moderately acidic soils. Our results show that agroecological practices can be effective at managing the incidence of bacterial wilt, allowing for significantly higher yields of solanaceous crops.

Keywords: Agroecology, bacterial wilt, management, solanaceous crops

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Diversity and management of parasitic nematodes associated with *Fusarium* wilt disease on cotton in Benin

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Plant-parasitic nematodes cause an estimated $80 billion in yield losses annually worldwide in various crops among which cotton. The reniform nematode *Rotylenchulus reniformis* Linford and Oliveira, for example, not only reduces seed cotton yields but also depreciates the quality of the fiber and seed reducing yield from 15 to 75 % depending on infestation levels and weather conditions. The damages of nematodes are usually followed by pathogens infestation such as of *Fusarium oxysporum* f.sp *vasinfectum* leading to a complex disease development. In Benin, *Fusarium* disease was reported in 2021 with enormous damage (up to 70 % of lost) in cotton fields. But till now, no comprehensive studies have been yet done on parasitic cotton nematodes and their interaction with wilt disease caused by *F. oxysporum* in Benin, although such studies are essential for proper management. The main objective of this study is to reduce yield losses caused by *Fusarium*-nematodes complex disease on cotton using environmentally-friendly and sustainable methods. Specifically, this study will: 1) determine cotton producers' knowledge of cotton wilt, nematodes and methods used to manage them; 2) establish the diversity and distribution of cotton parasitic nematodes in Benin; 3) develop integrated management methods using the combined amendment to soil of biochar, cow dung and poultry manure for plant parasitic nematodes and *F. oxysporum* associated with nematodes in complex diseases. Thus, the expected results of this research project are: 1) the knowledge of cotton producers on wilt, nematodes and their management method is known; 2) the map of the diversity and distribution of cotton nematodes in Benin is established; 3) the sanitary status of cotton fields due to the damage caused by the interaction between nematodes and the *Fusarium* is known; 4) an integrated method of control of cotton nematodes, *Fusarium* and the complex disease is developed. Thus, for agriculture in general, this research project will contribute to a better valorisation of crop residues (by the manufacture of biochar), the management of plant pests by inexpensive and environmentally friendly methods, thus preserving the health of producers and allowing at the same time a better crop production.

Keywords: Benin, cotton, *Fusarium oxysporum*, management, nematode

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Rearing parasitoids for biocontrol experiments: Could laboratory conditions influence sex-ratio?

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Parasitoids are insects whose larvae develop on or within a host, killing it when they reach maturity. Parasitoids can be used as biocontrol agents against certain pests after they have been tested in the laboratory. This requires a stable supply of individuals. However, sex-ratio is known to fluctuate greatly in parasitoid populations reared in the lab. With an insufficient number of females being born, the colony can die out. Different mechanisms related to individual biology and population ecology are involved in sex allocation. Given this complexity, it is difficult to know the exact cause of these fluctuations, but conditions in the laboratory are a possible source. We hypothesised that parameters that influence sex-ratio would appear more often in articles mentioning sex-ratio. We conducted a systematic literature review using Web of Science, using the terms rear, parasitoid, mass, population, method, factor, effect, environment and parameter. The search yielded nine hundred and thirteen articles. The parameters investigated were sex-ratio, temperature, humidity, pressure, diet, environment structure, host quality and population dynamics. Occurrences of each topic were counted programmatically using a list of twenty-nine keywords. Pressure, humidity and host quality were the least often mentioned, totaling together approximately 5 % of hits. Environment structure, population dynamics and sex-ratio together amounted to 25 % of hits. Temperature and diet were mentioned in 90 % of papers. Sex-ratio and host quality had the highest correlation between the number of mentions. However, an analysis of variance concluded that the mention of sex-ratio had no significant influence on the number of mentions of other parameters ($p = 0.297$). Furthermore, a chi-square test concluded that the mention of sex-ratio had no significant influence on another parameter being mentioned at all ($p = 0.339$). The Jaccard index was calculated for all possible pairs of parameters. The most strongly associated topics were temperature and diet.

Keywords: Biocontrol, sex ratio, systematic review, text analysis

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On-farm evaluation of push-pull system for stem borers and *striga* management on sorghum in northeastern Ethiopia

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The lepidopteron stemborer (*Chilo partellus*) and parasitic *Striga* weed (*Striga hermonthica*) caused major yield losses in subsistence sorghum production in the Eastern Amhara Region, Ethiopia. Various stemborers research results did not achieve the target in the management system. This study evaluated different number of *Brachiaria* (Mulato II) rows planted around sorghum plots. *Desmodium intortum* intercropped with sorghum in each *Brachiaria* row. The study was conducted on 61 farmers' fields in 2017 and 2018. The treatments were arranged as one row *Brachiaria* + *Desmodium*, two rows *Brachiaria* + *Desmodium*, three rows *Brachiaria* + *Desmodium* and mono-sorghum. The pooled two years and three locations data showed a significant difference ($p < 0.001$) between push-pull and mono-sorghum plots. Sorghum damage of 17.2 %, 16.4 %, 33.6 % in three, two and one rows of *Brachiaria*, respectively. The mean number of *Striga* was significantly reduced in push-pull plots (3 Striga m^{-2}) as compared to mono-sorghum plots (15 Striga m^{-2}). In addition, significantly high sorghum grain yields were recorded in three rows (4.5 t ha^{-1}) and two rows (3.7 t ha^{-1}) of *Brachiaria*. Yield increments of 104.2 % and 62.2 % and 50.0 % over mono-sorghum were recorded in three, two rows and one row of *Brachiaria*, respectively. In addition to sorghum yield increment, farmers were able to get a dry biomass yield of 1.7–24.6 t ha^{-1} in different rows of *Brachiaria* and 0.47–2.43 t ha^{-1} of Desmodium for their livestock feed. The three rows of *Brachiaria* were superior to the other rows, but farmers could also use the two rows as an alternative option with the combination intercropped *Desmodium*.

Keywords: Farmers perception, FRN, FRG, parasitic weed

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Agroecology and organic production

Applying agroecological principles to transform food systems, while narrowing evidence gaps in the Global South

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Agroecology is increasingly gaining scientific and policy recognition as an approach with the potential to address the environmental and social issues within food systems that unevenly affect the two-thirds of the world who are poor and practice farming as their main source of income. As a dynamic concept that encompasses a scientific discipline, an array of sustainable agricultural practices and a social movement, agroecology embraces a set of universal principles, yet agroecological designs rely on context-specific knowledge and tailored practices that are oriented at offering contextually sensitive solutions. This flexibility challenges the robustness, contextual validity and comparability of the generic sustainability indicators with which agroecology's performance is currently being measured and captured in the global evidence base that informs decision-makers. The gap between generic scientific knowledge and local knowledge in agroecology calls for a holistic, participatory and inclusive approach to producing evidence that integrates contextualized science and local (including indigenous) knowledge of all relevant food system actors (FSAs). As part of its 2030 research and innovation strategy, OneCGIAR and partners have started a new science-for-innovation initiative in agroecology that attempts at narrowing this gap by facilitating transdisciplinary interactions between researchers, small-scale farmers and other FSAs beyond the farm (e.g., extension services, NGOs, private sector, policymakers, funders and investors) in seven low-income countries, namely Burkina Faso, India, Kenya, Laos PDR, Peru, Tunisia and Zimbabwe. The initiative "Transformational Agroecology across food, land, and water systems" (AE-I) will, at its core, establish an international network of Agroecological Living Labs (ALLs) that will explore either of following three transition pathways, namely (i) agroecologically "intensifying" farming systems that currently exhibit low productivity due to low input use; (ii) "redesigning" small-scale farming with high external input use; and (iii) "converting" profitable medium-scale enterprises with high external input use. Agroecological inno-

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vations (i.e., technologies and practices, business models, and institutional arrangements) will thereby be equitably co-created and tested in the ALLs, thus addressing the questions of whether and under which circumstances these innovations work, are adopted and scaled in the specific environmental, sociocultural, economic, and political contexts of the prioritised food systems.

Keywords: Agroecological principles, agroecological transitions, agroecology, Burkina Faso, co-creation, food systems transformation, India, Kenya, Laos PDR, Peru, Tunisia, Zimbabwe

Agroecology approaches to enhance learning in a changing world: Experiences from southern Africa

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Climate change and a rapidly changing market context requires accelerated learning and adaptative capacity. This is key to local generation of suitable solutions to agricultural problems. Agroecology provides a foundational approach, one that emphasises understanding principles, harnessing biological processes, and enhancing local capacity. In Zimbabwe and Malawi agroecology approaches including participatory action research and living laboratories are part of an on-going learning process with rural communities, researchers and other stakeholders. Malawi aAgroecology living laboratory was established in 2013 and has supported farmer agency around soil health, crop diversification and sustainable intensification over the last decade. The Zimbabwe living labs are being established in "food territories" to support innovation and strategies for evaluating benefits of integrating various short and longer-term agroecology approaches implemented at farm-scale. Near term approaches include control of the pest Fall Armyworm using legume intercropping strategies, climate-adapted push pull and conservation agriculture systems with beneficial effects on natural enemies, such as ants, which suppressed this insect pest. Longer-term opportunities include payments for ecosystem services for key value chains and inclusive financing modalities are a novel and important approach. Generation of an expanded menu of agronomic innovations, continually generated and extended as options fit for contexts is underway. Scaling of on-farm experimentation is now possible and happening, where farmers generate innovations, along with researchers. This presentation will explore two decades of co-learning on farmer-centric Agroecology in maize based cropping systems in Southern Africa. New directions in terms of living laboratories being initiated in food territories of Zimbabwe, and action research renewed in Malawi will be explored.

Keywords: Agroecology, living laboratories, Malawi, Zimbabwe

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What is the contribution of organic agriculture to sustainable development? A synthesis of 12 years of long-term trials SysCom

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Organic agriculture (OA) is advocated for its benefits to human health, environment and socio-economic well-being of farming communities. However, there are concerns about its productivity and economic sustainability. Research conducted mainly under temperate conditions in developed countries has demonstrated the potential of OA. However, empirical evidence on the performance of OA under tropical conditions is still limited.

In 2006–07 FiBL started the 'Long-term Farming Systems Comparison in the Tropics (SysCom) Program' in collaboration with local partners in three tropical countries to produce scientifically sound data on the agronomic, ecological and socio-economic performance of organic and conventional production systems over a long-term. The programme comprises of a network of four long-term experiments (LTEs) in Kenya, India and Bolivia, in concert with participatory on-farm research (POR) aimed at developing locally adapted sustainable technologies. Our research in the tropics shows that organic agriculture respectively agroforestry systems have large potential to contribute to sustainable development especially in the field of soil fertility and biodiversity conservation while productivity and profitability is usually equal. Higher returns on investment and higher labour productivity make organic and agroforestry systems interesting for resource poor small-holder farmers. A more pronounced role of organic inputs such as compost, manure or litter-fall into the systems leads to a slow but steady built-up of soil organic matter, even under tropical conditions.

Yet, for full exploitation of the benefits of organic agriculture major efforts are needed to tackle agronomic/ technological challenges (lack of input, pest management), capacity development for farmers (technical know how) and institutional/governance challenges (markets, agri-business).

Keywords: Agroecology, cross-continental comparison, food security, long-term trials, organic farming

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Agro-ecological transformation: experiences and issues with variety development of indigenous Sahelian crops in West-Africa

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Variety and seed issues are at the heart of agro-ecology as a social movement. These issues, however, have received little attention from the scientific plant-breeding communities. Key entry points could be diversity, co-creation and knowledge sharing and responsible governance of variety and seed dynamics. Indigenous staple-crops in Sahelian West Africa and the farming communities creating and maintaining varietal diversity over millennia offer ideal cases for learning how plant breeding can be organised on agro-ecological principles. We seek to understand a) how current varietal-development activities for these crops align with agro-ecological principles, and b) what opportunities exist for (re)organising these activities to strengthen their application for optimising environmental benefits and social- and economic improvements for smallholder farmers.

National-programme breeders (NPBs), farmer organisations and NGO representatives shared their experiences in sorghum, pearl millet or cowpea varietal creation and use through online discussions. Discussions focused on a)

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setting priorities b) choosing and using germplasm to create new diversity, and c) testing and selecting the resulting breeding products. The breeders in Senegal, Mali, Burkina Faso and Niger provided additional written feedback on the initial synthesis of findings.
Joint efforts by smallholder farmers and NPBs for creating new varieties are underway. Breeding programmes are developing product concepts and profiles for prioritising what types of varieties to breed. The specific activities conducted however are, to a great extent, determined by short-term project funding. Attention to agro-ecological outcomes was mostly limited to increasing income for smallholder farmers. Varietal creation to enhance biodiversity, capacities for sharing knowledge and skills, or responsible governance of seed and variety dynamics were not directly addressed by the NPBs.
Breeders extensively use local germplasm for generating new diversity. Purification and registration of local varieties in response to farmers' requests was sometimes reported.
Joint testing and selecting of breeding materials by farmers and researchers was widely reported. This was mostly limited to advanced generations evaluated under recommended fertilisation as sole crops. NGOs and farmer organisations often requested that joint planning with NPBs be held from the beginning.
Entry points for strengthening and (re)organising breeding activities in line with key agro-ecological principles will be discussed.

Keywords: Biodiversity, cowpea, participation, pearl millet, sorghum, variety development

How agroecology can help overcome governance challenges to cocoa mass spraying in Ghana

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There are growing concerns about rising pesticides (i.e., herbicides, insecticides, fungicides) used in global agriculture. These concerns include mounting evidence that excessive pesticide use obliterates biodiversity, contaminating groundwater and food while risking humanity's exposure to carcinogens. Consequently, in a recent report, the FAO, UNDP & UNEP call on governments to repurpose, starting with reviewing how existing subsidy programs affect livelihoods and nature. This paper responds to this call by critically analysing Ghana's cocoa mass spraying programme (CMSP), which the government introduced to improve the country's cocoa production and foreign exchange earnings. Data were collected from 125 actors, including government officials, cocoa farmers, cocoa purchasing companies, and non-governmental organisations in Ghana's Juabeso district through interviewers, focus groups and process net maps, and content analysis to identify the actors' experiences with the CMSP. The findings reveal a complex mix of actors riddled with multiple governance challenges that impede the effective delivery of the CMSP. The CMSP has nurtured a pesticide treadmill within the communities. However, because the programme cannot address farmers' agrochemical demands adequately, multiple farmers use lower doses of agrochemicals or explore unapproved agrochemicals, posing health and safety risks to the farmers and increasing the chances of creating agrochemicals resistant pests and diseases. Moreover, farmers are already losing a good part of their cocoa to pests and diseases, affecting their incomes and wellbeing. The findings raise questions about the sustainability of the CMSP and cocoa livelihoods. Therefore, we reflect on how adopting agroecology approaches can help mitigate the existing pesticide treadmill and improve the chances of future-proofing cocoa production to protect lives and livelihoods in the region.

Keywords: Cocoa agroforestry, food systems, pesticides, subsidies

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The role of school gardens in environmental education and agroecology in Ghana

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The application of ecological principles to agricultural systems and practices is becoming increasingly popular around the world. Agroecology and environmental education may be promoted through school garden projects (SGP). In Ghana, societies' growing awareness of the fundamental role school gardens can play in environmental education and community adaptation to cannot be underestimated. Although the concept of school garden is not new in Ghana, it is only being implemented in a small number of schools. This article focuses on school gardening and the obstacles to its implementation in Ghana. The study used a mixed method approach involving literature search in Google Scholar, Science Direct, and Scopus. In addition, several schools and stakeholders of school garden programmes were interviewed. The study revealed that Ghana is making efforts in environmental educational activities, but has yet to successfully integrate the concept of school gardening into classroom curriculum. There is also limited collaboration between schools and the wider community, as well as limited funding for establishing a school garden. The promotion of SGP in Ghanaian schools is hampered by these issues. The promotion of environmental education and agroecology through SGP can gain recognition when properly integrated into school's curriculum. As a result, the study suggests that SGP can be improved by 1) involving community and relevant stakeholders to promote the benefits of school gardening for positive learning outcomes and behavioural improvements, 2) incorporating it into educational policies/school curriculum to allow students to connect and interact with the natural environment, 3) providing financial support to ensure its long-term sustainability.

Keywords: Agro-ecology, environmental education, school garden

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Agroecological practices and the water planetary boundary

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Rising demand for agricultural food production and at the same time rising crop water demand are putting a sustainable use of water resources for agricultural production increasingly at risk. A central question therefore is: how can agricultural production take place without transgressing crucial boundaries of sustainable water use? The Planetary Boundary concept offers a framework which quantifies such sustainability limits of fresh water use and land-system change and defines a so called "safe operating space" within sustainability limits. This safe operating space is transgressed, when a control variable (e.g. minimum river flow) triggers the destabilisation of a related response variable (e.g. aquatic biosphere integrity). Planetary Boundary assessments however, often focus on boundary transgressions at global scale and it is difficult to operationalize the framework for sustainable actions at local farm or agricultural system scale. For this reason, our conceptual study focuses on defining and discussing sustainability boundaries on agricultural system scale. Here we concentrate particularly on the definition of local water boundaries. We discuss potential control and response variables, which could be used to decide whether an agricultural system is functioning within water boundaries or if it is at risk to transgress these and to destabilise a local or even global response variable. Acknowledging that the answer to this question can't be universal and highly depends on the local environment, we propose local water related control and response variables for selected agricultural systems and environments (e.g. rainfed vs. irrigated systems). In addition, we pose the question if agroecological measures can support farming within a safe operating space and which agroecological measures could help to prevent a transgression of local water boundaries? Setting clear limits to water use in agriculture and highlighting the potential of agroecological measures to expand agricultural activities within these limits, can foster a more sustainable water management, which considers local as well as global impacts of agricultural water use.

Keywords: Agroecological practices, sustainability boundaries, water planetary boundary

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The myth of agroecology – examples from Uganda

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Not only in the Northern Hemisphere, but also in the South, there is a hype on agroecology, however, what's behind this term, when we look into practice? Agroecological practices (AEP) mainly refer to crop rotation, inter- and mixed cropping, mulching, composting, biogas (compost and slurry), mechanical weed control, bio-pesticides, reduced tillage intensity, hedges and agroforestry, i.e., alley cropping, trenches, terracing, water and soil conservation, etc. – practices that are known for decades, however as single activities, while in case of organic farming as a systems approach.

In the mainly slopy Rwenzori region of Uganda, seven farms - two large coffee / tea farms (organic and mainstream) and five mixed so called agroecological oriented smallholder farms with banana, coffee, vegetables, root crops and goats / chicken, have been assessed via field walks, qualitative interviews, supported by a rich photo documentation. We classified AEP according to their relevance for soil erosion (soil fertility) control, climate change adaptation and mitigation, biodiversity and farm output. Reasons are discussed under which conditions AE practices are established with high / low quantities and qualities, or not.

We conclude that the farming systems are diverse, but the implementation of AEP is more an exception than mainstream practice, and thus soil erosion and risk of landslides is high, biodiversity loss is on the rise and farms contribute to climate change. Where successfully implemented – as on one large and one smallholder farm, profound knowledge and long-term experiences, technical competences and, in the case of smallholders, group driven exchange and activities on practices, as well as well-developed access to markets for all farming systems, are crucial.

Keywords: Agroecology, farming systems, organic farming, smallholder farming

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The role of agroecological systems (agroforestry and intercropping) and innovations in increasing crop production in a sustainable environment

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Agriculture must meet the persistent challenges of hunger, malnutrition and diet related diseases in this 21st century - under increased population, loss of natural resources, soil degradation and climate change issues. While past agricultural systems focused on producing more food for the population, today's challenges include factors such as climate change, environmental degradation and human health issues that typically demand new approaches and systems. In many countries, current innovation approaches are promoted by agribusinesses and biotechnology industry that intend to produce more output for high revenues while neglecting their effects on the environment and humans most especially vulnerable populations such as refugees and displaced people. These approaches impede rural communities to produce and access health foods in sustainable environment. Unless the efforts are increased, the world will not achieve SDGs 1&2 of Ending poverty and zero hunger respectively. There is a need for a paradigm shift to more sustainable agricultural systems – Food and crop systems that are able to produce more but have less on the environment. In many instances agriculture has been portrayed as the main cause to the environmental degradation, but of recent many researchers have recognised that it is possible to have agroecological systems that do not harm the environment. Agroecological farming approaches such as agroforestry, intercropping, no tillage put into consideration the effects agricultural activities on the environment. They also emphasise the importance of local knowledge and prioritises farmers' ideas to policy makers and other stakeholders. Agroecology farming will play a fundamental role in increasing food production and enhancing food security and nutrition, building resilience at the same time restoring biodiversity that is vital for sustainable agricultural production. Several studies indicate that, over time, agroecological food systems attain more stable levels of total yield per acre at a low cost of productions than other systems that focus on use of high inputs levels that prove costly. However, for an agroecological farming systems to be economically, politically, socially and environmentally acceptable there is a need to invest public funds and design inclusive public policies and also fulfil these criteria a) environmental and b) social-economic dimensions.

Keywords: Agroecological farming, biodiversity, climate change, health issues, innovation approaches, malnutrition, paradigm shift, public policies, sustainable agricultural systems

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Assessment of agroecological knowledge and training needs of small-scale farmers in West Africa

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Burkina Faso and Senegal – host countries of the NUTRiGREEN project - can be described as hotspots of climate change due to their projected population increase, their vulnerability to climate change and general food insecurity. As a consequence it is now more important than ever a) to assist their efforts to transform how and what foods are being produced and consumed, b) to adapt the local agricultural systems to the impacts of climate change, c) to minimise the negative impacts of the food system on the environment of the region, on consumers' health and the economic well-being of all actors in the food system, in order to provide everyone with a sustainable future. The NUTRiGREEN project - running from June 2021 till May 2024 - examines the value chains of traditional African plants, to determine the incremental, systemic, and transformative adaptations required to boost their impact in the local and regional agri-food system. Climate-resilient and agroecological practices are at the centre of the project design. The NUTRiGREEN team conducted a household survey in March and April 2022 with 400 small-scale farmers to understand the local production system as well as consumption pattern. In parallel, NUTRiGREEN started the first phase of the so-called climate field schools. Thereby the training needs of research farmers on agroecological knowledge (pre-season) are assessed. This activity is conducted to understand the existing agroecological knowledge and practices. These insights are used to identify the training needs that are being addressed as part of the climate field schools, which are designed to build smallholder capacity. This is later followed by an evaluating of learning after the 2022 season. The planned poster will highlight the key findings of the household survey and the climate field schools on the on agroecological knowledge of the local small-scale farmers and make suggestions for needs-based trainings and locally fitting diffusion strategies.

Keywords: Agroecological knowledge, Burkina Faso, household survey, needs assessment, Senegal

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Productivity in diverse production systems: Insights from the Elgon highland agroecosystems of Uganda

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The Elgon highland agroecosystems are characterised by diverse production systems, including livestock, perennial and annual crops. This therefore plays a major role in contributing towards food and nutrition security. However, increasing population densities in the area, reflected in the low cultivable area per household, is still a challenge in implementing sustainable production practices. To increase farm output, for subsistence and commercial purposes, agricultural strategies focus on conventional agriculture necessitating the use of fertilisers and pesticides. Farming households therefore operate under limited production alternatives from which they can choose probable possibilities. Alternative systems such as polycultures, and the use of local resources such as manure and mulches have not been emphasised in agricultural policies, yet they could be productive and contribute to sustainable agroecosystems. This study therefore compared farm productivity in smallholder farms from different production systems. The study focused on annual and perennial production systems. These production systems included both monoculture and polyculture. In the annual production systems, the crops included maize and beans, because the crops are the main food security crops. In the perennial production systems, coffee and bananas were of major focus because they contribute highly to household cash income. So the study seeks to understand to what extent food security is penalized to farmers who prefer agro-ecology production approaches as compared to conventional practices. Preliminary analysis shows that perennial polyculture production systems, involving a mixture of coffee and bananas are more labour saving as compared to coffee monoculture production systems. Less production time was also realised in the annual production systems where maize was intercropped with beans, when compared to beans in monoculture production systems, indicating a high returns per unit of farm labour. Agricultural policy strategies that aim to increase diversity in production systems could help to promote better use of resources, giving better yields, and thus, food secure households. Incorporating perennials in these systems also, contributes to soil protection through soil cover, hence supporting agroecosystem sustainability.

Keywords: Agroecosystems, Elgon highland, farm productivity, polyculture

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The agroecological approach for sustainable global food security

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The industrialised food system is showing that it is not sustainable in economic, social, or environmental aspects. However, the agroecological approach is holistic, balancing the focus on people and the planet. So with a deep understanding of the agroecological approach, the change needed to restore sustainability to food systems can occur. The agroecological approach has an essential role to play in the future of the global food systems. The agroecological approach uses the ecology of the food system and establishes farming and food systems that adjust to local environments. It has the explicit goal of transforming food systems toward sustainability, such that there is a balance between ecological soundness, economic viability, and social justice. The agroecological approach applies ecological principles and analysis toward the creation of more sustainable agriculture and food systems. The agroecological approach seeks to develop strategies to maximise long-term benefits. The agroecological approach incorporates indigenous local knowledge into the research and development processes and seeks to diversify biota, landscapes, markets, and institutions. Agroecologists work with different stakeholders to support empowering people. There is a deep relationship between culture and the environment in the agroecological approach. The livelihoods of smallholders, the elimination of hunger, the restoration of the earth's agrobiodiversity and agroecosystem resilience would all be better served under the agroecological approach. It focuses on the critical agents of change – family farmers, indigenous peoples, fishers, rural women and youth. Therefore, by integrating scientific evidence with local indigenous knowledge, the agroecological approach can contribute to sustainable global food security while maintaining the natural resource base.

Keywords: Agrobiodiversity, food security, local knowledge, sustainability, transdisciplinary

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Confronting farmers' perspectives with agronomic findings for the co-design of agro-ecological options in Burkina Faso

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Smallholder farmers in Burkina Faso are facing many challenges including poor soil fertility combined with unpredictable weather conditions and weak market infrastructures which increase their vulnerability to climate change. To increase the potential uptake of agro-ecological options, this study aims at tailoring the options to the smallholder farm context. We used an iterative approach following the Describe-Explain-Explore-Design (DEED) cycle to co-conceive, test, and co-evaluate agroecological options with farmers of different types. Agronomic trials were conducted in 2021 in two communities (Nagreonkoudogo and Tanvousse) of the Nagreongo commune in the soudano-sahelian zone of Burkina Faso. Each trial consisted of a randomised split plot of six treatments with four repetitions. The treatments included monocropped sorghum and cowpea, sorghum-cowpea line intercropping, traditional sorghum and cowpea intercropping (intra poquet intercropping), *Mucuna rajada* and short fallow with *Crotalaria retusa*. During a field visit, a voting evaluation of the tested options was conducted with the farmers at maturity of the cowpea. A second evaluation after harvesting used farmers' own criteria. Results showed that the land equivalent ratio (LER) of the traditional intercropping in both Tanvousse (1.03) and Nagreonkoudogo (1.27) were larger than those of the 2/2 lines intercropping at 0.62 and 0.83, respectively. In Nagreonkoudogo, the first ranked option of the male and female farmers was the 2/2 lines association and the traditional association, respectively. In Tanvousse however, male farmers ranked the monocropped cowpea first, while female farmers chose *Crotalaria retusa* and the monocropped cowpea with the same score. Looking at the yield performance criteria, most farmers in general were satisfied with yield in Nagreonkoudogo as compared to Tanvousse this corroborates with average yield data. However, even though, agronomic results showed the relative advantage of the traditional association compared to monocropping, 100 % and 92 % of farmers were satisfied with yield performance of monocropping and traditional association respectively in Nagreonkoudogo. In Tanvousse, 57 % positively valued both traditional association and sorghum monocropped. Farmers yield performance assessment is in accordance with average yield but not with relative yield (LER). This implies the necessity of farmers and scientists to work together in the process of the co-conception.

Keywords: Agro-ecological options, co-conception, co-evaluation, farmer's criteria

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Convergence and divergence of smart and precision farming technologies, agroecological principles and smallholder agriculture in Africa

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Agroecological approaches and smart and precision farming technologies can potentially increase productivity of smallholder agriculture while maintaining the ecosystem's capacity to deliver ecosystem services supporting resilience and sustainability of related agri-food systems. Science-based understanding of agroecological mechanisms and methods attracted interest at multiple levels including policy and civil society as such holistic approaches address best complex societal and environmental challenges the agri-food sector is facing at multiple scales. Furthermore, agroecological approaches can aid in achieving various Sustainable Development Goals, specifically through the application of ecological principles to agriculture, the use of regenerative practices to natural resources and ecosystem services, and by addressing social equity and responsibility. Beside of benefits associated to agroecological approaches, increasing evidence from research considers that affordable smart and precision farming methods and technologies such as insect and disease detection, crowd sourcing, precision irrigation, nutrient calculators, mapping and remote sensing technologies are promising for smallholder agriculture in developing countries. However, such beneficial technologies may cause simultaneously negative effects or trade-offs to be assessed prior to their implementation at larger scale. Hence, we apply a holistic approach by using the High-Level Panel of Experts on Food Security and Nutrition (HLPE) consolidated list of agroecological principles, which are based on FAO's elements of agroecology, to evaluate challenges, potentials and the feasibility of affordable smart and precision farming technologies with specific regard to improving productivity, resource efficiency, resilience, social equity and responsibility. Thus, this review aims to systematically gather knowledge on smart and precision technologies supporting agroecological approaches appropriately prepared for immediate transfer to farmers, advisors, researchers and policy makers.

Keywords: Agroecology, digital agriculture, precision agriculture, smallholder farming, smart farming

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Using best practice approach to build resilience in organic cotton systems in central India

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Cotton plants are a primary sources of worlds' industrial textile and it is estimated that globally approx. 2.78 % of arable land is under cotton plant cultivation. Conventional cultivation of cotton is a highly input-intensive process, requiring large quantities of pesticides, fertilisers and water resources. Growing cotton organically can significantly reduce negative environmental impacts of cotton. However, yield of organic cotton is often recorded to be lower than the yield of conventional cotton. There is a need to develop system-based approaches that increase productivity of the cotton systems. Our study is based on a long-term trial that has been comparing organic and conventional cotton systems since the year 2007, in central India. In our study region cotton is grown in a two-year crop rotation with wheat and soybean. For better adaption of organic cotton production, it is crucial to increase overall economic returns from all crops involved in the cotton rotation system. In the initial phases of our study we recorded a yield gap of up to 25 % between organic and conventional cotton production. To mitigate this yield gap, we adopted multiple best practice approaches using agroecological principles. Our recent results show that such approaches can not only reduce the yield gap but also increase soil organic carbon in the organic cotton systems; resulting in systems that are potentially more resilient to climatic changes. We will discuss our results and highlight the need to invest in agroecological and socio-economic research to eliminate yield gaps between organic and conventional agriculture and to identify barriers to adoption of sustainable techniques.

Keywords: Adoption, best practice approach, cotton, organic, system productivity, yield gap

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Development of rural communities and food security in Iran based on agroecological farming methods

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Iran, with more than 60,000 villages in different climates, has a high potential to benefit from various agroecological methods. Many villages in Iran are in unfavourable environmental, economic and social conditions, which has led to the migration of villagers to cities, food insecurity, land degradation, deforestation, etc. Therefore, by using various agroecological methods, these problems can be overcome to some extent. Agroecological farming consists of a variety of environmentally friendly farming methods that can produce crops or livestock without harming natural ecosystems.
Suburban and urban permaculture is a method to efficiently and optimally exploit space for food production and minimise wasted space. Multiple or mixed cultivation is the cultivation of two or more crops in the land during a growing season instead of planting only one crop, which reduces overall input costs, fertiliser, irrigation and labour costs, and leads to increased farmer income and better farm management. Mixed farming, that means growing crops and raising animals to produce meat or eggs or milk, together. Agricultural forestry is a land use management in which trees or shrubs grow around or between crops or pastures that lead to improve soil fertility, crop diversity and food resistance to climate shocks and increase income, diversity, carbon sequestration and reduce deforestation and erosion. Crop rotation is a method involving the cultivation of a variety of crops in an area in a series of growing seasons that reduce the usage of fertilisers, herbicides, and increase field resilience. Finally, the agroecological village method encompasses five stages including community identification, employment and strengthening of social organisations, educational and agricultural planning, implementation of the basic level and monitoring. This method is a logical evolution in rural development planning as it provides a comprehensive approach to the social, environmental and economic development of Iranian communities; by developing this method, the agricultural production will be increased and food resources for the growing population of Iran will be provided. The health, culture, income and economy will be improved, too. In this method, it is essential that different rural people be effectively involved in participatory processes, training sessions, and consultation networks.

Keywords: Agroecological farming, farm management, methods, rural communities

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Indicators of soil quality, health and cultivation environment in an agroecological cropping system

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The initial validation of the indicators was carried out on small scale family farms linked to an association of agroecological producers in municipalities around Anapolis, Goias state, Brazil. To validate, train and encourage use by the producers, we sought to identify and quantify the current state of soil conservation and the visual health status of crops and vegetation used in the participating farms. The quite diversified production of the farms used to validate the indicators involves fruits, vegetables, eggs and derivatives of honey, sugar cane and cow milk, all produced using agroecological principles. Farmers often use fallow and crop rotation, and the crop choices consider regional market opportunities, local farmers' markets, and digital channels (virtual delivery market). The indicators can provide important information about the agroecosystem and the relationships and integrations between management practices and the sustainability of farms. Once validated, they will make it possible to verify, quantify, visualise, and compare the adopted management practices among farms, and facilitate the choice of the most appropriate ones, according to the available resources. The initial validation of the indicators evidenced the need to include soil cover crops as green manure to manage the farmers' cropping systems. Using soil improvement and conservation practices were also identified. And the need to develop alternatives for coexistence with weeds as an essential quantified demand. The indicators used in the initial validation made it possible to highlight, evaluate and quantify sustainability in most farms. It was demonstrated that soil conservation is the activity in which farmers focus the most care, highlighting the importance of management practices to control soil erosion and water use.

Keywords: Agroecological farming, crop rotation, diversification, family farming, horticultural production, sustainability indicators

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Agroecological practices and drivers of adoption by arable crop farmers, Cross River State, Nigeria

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Global food production is plagued by a myriad of challenges such as climate change, population explosion, pollution, food quality and natural resources conservation. Agroecological farming is gaining recognition as one of the possible solutions to these challenges. However, the rate at which agroecological practices are being adopted has remained low. This study therefore examined the agroecological practices and drivers of adoption by arable crop farmers in Cross River State, Nigeria. A multistage sampling procedure was used to select 120 household heads. Data were collected with the aid of a set of structured questionnaire and were analysed using descriptive statistics and a binary logistic regression at 5 % level of significance. Some of the agroecological practices adopted by arable crop farmers were: intercropping (100 %); green manure (95.8 %); and scarecrows (95 %). Those least adopted were: using natural enemies (4.2 %); no tillage (5.8 %); and alley cropping (14.2 %). The three main drivers of adoption of agroecological practices were: it boosts crop yields thereby ensuring food security (MS=4.89); inputs (e.g. local farm wastes) are locally available (MS=4.78); and it helps farmers to adapt to/and cope with climate change (MS=4.77). Some of the farmers' perception on constraints to the use of agroecological practices were: increase demand for food and raw materials due to population growth leading to overexploitation of land and use of external chemical inputs (MS=4.79); lack of incentives to farmers from government to boost use of practices (MS=4.7); limited farmers' awareness and knowledge on existing agroecological practices (MS=4.66). The binary logistic regression model showed that the chi square was not statistically significant (x2 (8) =10.99; $p = 0.202$). Furthermore, sex ($p = 0.032$) and extension agent contact ($p = 0.027$) had significant positive effects on the adoption of agroecological practices at $p = 0.05$. In conclusion, government should promulgate policies that favour the adoption of agroecological practices, while agricultural extension services should be tailored towards farmers' skills improvement for effective implementation of agroecological practices.

Keywords: Adoption, agroecological practices, arable crop farmers, drivers, sustainable agriculture

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Evaluation of the transition potential of farms towards agro-ecology in two African regions

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A major challenge of West African agriculture to ensure food security is to promote the agro-ecological transition of farms and its amplification on a territorial scale. The present study aims at assessing the potential for the evolution of cereal and market garden farms towards more ecological practices in two regions from different countries but with similar pedoclimatic conditions. A typology based on soil fertility management and conservation practices was carried out from surveys of 650 farmers in six areas of the Atacora (Benin) and Houët (Burkina Faso) provinces. In neither region exclusively organic or agroecological farms are currently found. The typology made it possible to define types of farms on the basis of their acreage, the intensity of use of mineral and organic fertilisers and pesticides, the density of livestock and the intensity of implementation of agro-ecological practices. A greater diversity of agro-ecological practices is observed on farms in Burkina Faso compared to farms in Benin. Vegetable crops benefit more from organic fertilisation compared to cereal crops. Livestock farming is extensive and characterised by traditional production systems. Moreover, these farms present common assets but also specific challenges to be met in terms of the use of synthetic pesticides and reasoned fertilisation, the use of crop residues and the integration of agriculture and livestock for an agro-ecological transition. Strengthening the capacity of farmers to embrace agro-ecological principles and implement agro-ecological practices at the territorial scale must be a priority for public authorities and development partners to develop strategies to support farms towards a dynamic agro-ecological transition.

Keywords: Agroecology, Benin, Burkina-Faso, survey, typology

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Agroecology as solution to land degradation: Vulnerability and resilience in far North Region of Cameroon

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In the context of sustainable development, agriculture occupies an important place since it significantly impact the natural resources. Particularly, it plays a key role in the development of the territories, and it meets one of the most fundamental human needs (nutritional role). Thereby, the sustainability of agriculture is a necessity for farmers and for biodiversity. However, producers face a changing climate that contributes to exacerbating poverty and social tensions. Thus, vulnerable farmers in the semi-arid zone of North Cameroon have implemented several practices and techniques to cope with land degradation. This study therefore identifies and assesses the various agro-ecological techniques implemented by vulnerable producers in response to land degradation within the council of Tokombéré, Cameroon. By means of a household survey 160 farm households interviews were conducted following a stratified random sampling technique and complemented with field observations. The analysis of the data reveals that the techniques implemented by farmers are different depending on farmer's geographical location. In the mountainous region, farmers grow crops on the terrace and use soil and stone bunds simultaneously. On the other hand, farmers in the plains, generally use half-moon, the zai, cultivation on ridges and beds to cope with land degradation. Moreover, in the plains, stone bunds have also been installed. Use of human urine as a fertiliser has also been a new practice. The field observations reveal that the locker and ridges were the most effective techniques on the plains. The field observations also show that soils in the mountains are less degraded and more fertile than those located in the plains. It is concluded that the restoration techniques applied in the mountain are more likely to enhance resilience than those applied in the plain.

Keywords: Agroecology, climate change, land degradation, resilience, vulnerability

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Agroecology in Burkina Faso, reconciling adaptation to production conditions and need for quality diets

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In Burkina Faso, a large proportion of the rural population relies on agriculture. However, the country faces major challenges, including food security and the preservation of natural resources in a context of continued population growth and climate change. In this context, where production conditions are harsh and continuously deteriorating, agroecology is emerging and is presented as an alternative to the conventional agricultural practices whose effects are increasingly proving to be unsustainable. However, can Burkina Faso rely on agroecology to meet the challenge of food security? In this study, we opted for a quantitative approach through inventory forms addressed to the different agroecology actors, complemented by semi-directive interviews in order to identify the actors, their promoted agroecological practices, describe their roles and their synergies in the promotion of agroecology in Burkina Faso. The results highlight, firstly, a diversity of actors, whose actions for the promotion of agroecology are equally varied, and secondly, a wide range of promoted agroecological practices and techniques. Some of them are proven either scientifically (technical sheets) or build on through local experience. Secondly, funding, membership, technical support and research are windows to observe a networking of agroecology actors (synergies) which is a prerequisite for the effectiveness of actors in the production. Agroecology has a great potential for developing safe food systems and contributing to poverty alleviation in Burkina Faso. However, the sector already suffers from ills such as the issue of leadership, the lack of financial resources and the weak capacities of the actors that limit the development of agroecology. In addition, dissemination and adoption of agroecological practices are not widely accepted and promoted actions are oriented to cash production for the privileged equitable market (organic label) and not production for common people.

Keywords: Agroecology, Burkina Faso, food security, sustainability, transition

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Crop productivity improvement in organic agriculture through a system-based approach

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Contributing to the global debate if organic can feed the world, the Research Institute of Organic Agriculture (FiBL) has started two long-term trials in Kenya. At each trial site (Chuka and Thika), conventional farming (Conv) and organic farming (Org) were compared at two input levels: high inputs (High) representing export-oriented, large-scale production, and low inputs (Low) representing smallholder production, mainly for domestic use. The conventional systems received mostly synthetic fertiliser and used synthetic pesticides. The organic system only used organic fertiliser and bio-pesticides. The differences between input levels were the amount of nutrients supplied, especially nitrogen and phosphorous, and supplementary irrigation. After twelve years of continuous cropping, we encountered some trends regarding productivity in organic and conventional systems: Grain maize, baby corn, and common bean achieved similar yields in organic and conventional, whereas cole crops, French beans, and potatoes showed significant lower yields in organic. Although organic systems showed positive effects on soil fertility, human health, and biodiversity, productivity (and thus food security) is essential for farmers and societies considering switching to a more sustainable farming approach. It is also good to note that the organic systems within the trials were guided by conventional mindsets -i.e., substituting synthetic products with biological ones without adapting other more system-based approaches. Thus, after four crop rotations (2007–2018), we adapted a best-practice approach feasible for farmers in the high input systems in the fifth rotation. For example, we used mixed cropping (push-pull) and improved plant extracts in the organic high input system to manage pests and disease. Preliminary results show that we were able to improve yields in organic systems significantly, e.g., yields in organic French beans production were higher in the fifth crop rotation than in the previous season, closing the gap between organic and conventional systems. However, we are still working to improve management practices in all the systems, focusing on water and soil fertility management.

Keywords: Farming systems, Kenya, long-term experiment, organic agriculture

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Influence of soil extractable nutrients on the walnut fruit ionome in southern Kyrgyzstan at different elevations

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The impact of climate change on ecosystems and plants is one of the main future challenges and due to altered precipitation and temperature increase may alter food quantity and quality. The expected changes in temperature may influence walnut plant physiology and thus fruit quality, as well as soil processes, such as mineralisation and therefore nutrient provision for plants. Increasing temperatures in Kyrgyzstan thus might result in changes of walnut quality in general and in particular in their nutrient content. Our research aims to investigate the influence of available nutrients in the soil on the nutrient content of walnut fruits (*Juglans regia* L.) in the walnut forests of Southern Kyrgyzstan. Soil samples were collected from top- and subsoils at three elevation levels (1000, 1300 and 1600 m above sea level) with similar vegetation but differences in average temperature as caused by elevation, acting as a proxy of future climate (low elevation representing future climate for higher sites). Walnut samples were collected from the same sampling sites and both, soil and walnut samples were analysed for soil physical and chemical properties. All soil properties showed high variability within sites but no differences between elevation levels. Physical properties of walnuts did not reveal any major difference along elevation either. Walnut fruit Ca and K content differed significantly between low and high elevation, however there was no difference observed for other elements. Elements in walnuts such as Zn, Mn, Cu and Na correlated with plant available soil Zn, Mn, Mg and Na, revealing a close relationship between some soil extractable plant nutrients and the plant ionome. However, differences in average temperature as caused by elevation did not affect available plant nutrients or the walnut fruit ionome. Temperature increase due to climate change may not affect walnut quality in the investigated forest systems. However, climate change effects, such as drought or altered precipitation patterns may influence walnut fruit development and should be subject of future investigations.

Keywords: Climate change, *Juglans regia*, Kyrgyzstan, plant available nutrients, soil, walnut

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Deep soil nutrient alterations after implementation of agroforestry in Brazilian cropland

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Soils in tropical environments are highly weathered and usually present limited nutrient availability. Phosphorus stocks are low due to high adsorption and potassium is easily leached to deeper layers. In addition, soil management practised by smallholder farmers is commonly based on low rates of fertiliser input, resulting in a negative nutrient balance. Agroforestry systems (AFS) are a viable alternative in such cases, due to their capacity to improve nutrient use efficiency. AFS may increase nutrient content in the top layers due to litter deposition, but what happens to the nutrients stock in deeper layers remains unclear. The objective of this work is to understand the soil nutrient dynamics in deep soil after the implementation of AFS in a Brazilian agricultural area.

We collected soil up to 3.0 m deep in an agricultural area (AG), AFS in intermediate stage (AFSi – 6yo), AFS in advanced stage (AFSa – 21yo) and a secondary forest (SF), and determined plant-available phosphorus (P) and potassium (K). All soils were red Ferralsol with high clay content.

In the long run, agroforestry reduced the plant-available P stocks in the soil. In the 0–20 cm layer, P stocks was 17.3 kg ha^{-1} in the AFSa, whereas it was 43.4 kg ha^{-1} in the AFSi and 30.4 kg ha^{-1} in AG. Different stocks were also encountered in deeper layers. In the 150–200 cm layer, AFSa had a stock of 14.7 kg ha^{-1} whereas it was 29.1 kg ha^{-1} and 27.2 kg ha^{-1} in the AF and SF, respectively.

For K, not much differences were found among the land uses up to 150 cm deep, but AFS seem to actively absorb K from deeper layers. The K stock in the 200–300 cm layer in AFSa was 130.7 kg ha^{-1}, compared to 238.9 kg ha^{-1} and 238.6 kg ha^{-1} of AG and AFSi, respectively. The stock in the SF was similar to AG and AFSi, with 283.6 kg ha^{-1}.

Agroforestry systems seem to influence nutrient stock in deeper soil layers and therefore deep soil should be taken into account in nutrient balance studies in areas of transition from agriculture to AFS.

Keywords: Phosphorus, potassium, soil fertility, tropical agriculture

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Composite of biochar and cooking ash as ameliorant for enhanced nutrient availability and microbial functions of tropical soils

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Soils in most tropical savannah ecosystems are acidic due to their non-calcareous parent materials. This limits nutrient release and efficiency of microbial functions, leading to low crop productivity. In an incubation experiment, we assessed the ameliorating potentials of a single addition of corn cobs biochar and its combination with kitchen waste ash or calcium carbonate (CaCO3) on chemical and biological fertility indicators of acidic soil. Petroplinthic Cambisol soil obtained from the Guinea savannah zone of northern Ghana was used for the experiment. Based on a predetermined lime requirement (0.6 CaCO3 t ha^{-1}) of the soil and calcium carbonate equivalent of the ash (63 %), we applied biochar at 10 t ha^{-1} (B10) and 20 t ha^{-1} (B20); ash and calcium carbonate (CaC) at 0.7 and 0.5 t ha^{-1} respectively. In addition, combined application of B10+Ash, B20+Ash, B10+CaC and B20+CaC were studied, each incubated for 8 weeks at 50 % soil water holding capacity. The treatment effects on soil physicochemical parameters including pH, mineral nitrogen (Nmin), available phosphorus and soil organic carbon (SOC) were examined. Further, we measured basal respiration, microbial biomass carbon (Cmic), and extracellular enzymes involved in carbon (β-glucosidase, β-cellobiosidase, and β-xylosidase), nitrogen (Arginine- and Tyrosine-aminopeptidase), and phosphorus (Acid phosphatase) cycling. The results revealed that lime (CaC and Ash) and their combination with biochar improved soil pH by up to 22 % and increased mineral nitrogen and available phosphorus content than in the unamended control soils. The B20+Ash amended soil showed the highest microbial respiration (+56 %) and Cmic (+45 %) compared to the control. Higher SOC in the biochar treated soil stimulated the activities of extracellular enzymes, especially C- and N-cycling enzymes in the biochar-ash amended soil. Co-application of 10 t ha^{-1} biochar and 0.7 t ha^{-1} ash showed greater increases in all the examined soil fertility indicators than when biochar was applied alone, even at 20 t ha^{-1}. The study, therefore demonstrated that co-application of ash with biochar boosted biochar´s liming abilities even at a low rate, resulting in soil mineral N and available P release and effective microbial functions in tropical acidic soils.

Keywords: Biological functions, chemical indicators, liming, savannah soil, soil acidity

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Soil respiration under different N fertilisation and irrigation regimes in Bengaluru, India

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Rampant urbanisation has led to different levels of agricultural management intensities/practices in urban and peri-urban agriculture (UPA) which affects the soils' physical, chemical, and microbial properties. This study was conducted to investigate the effects of different levels of mineral nitrogen (N) fertiliser and irrigation on CO_2 fluxes in typical crops during the Kharif (wet) and Rabi (dry) season under the monsoonal climate of Bengaluru, S-India.

To this end data were collected from Kharif 2017 to Rabi 2021 in a two-factorial split-plot experiment conducted under rainfed and irrigated conditions in on-station experimental plots at University of Agricultural Sciences Bangalore (UASB). Studied where the three rainfed crops maize (*Zea mays* L.), finger millet (*Eleusine coracana* Gaertn.), and lablab (*Lablab purpureus* L. Sweet) as well as irrigated cabbage (*Brassica oleracea* var. capitata), eggplant (*Solanum melongena* L.), and chili (*Capsicum annuum* L.). CO_2 emissions were determined using a ventilated closed-chamber system connected to a Los Gatos Research (LGR) multi-gas analyser (CO_2, CH_4, NH_3 and H_2O). Measurements were conducted from 7:00 am to 11:30 am and repeated from 1:00 pm to 6:00 pm.

Under irrigated conditions average soil emissions of CO_2 in maize were 30 % lower than in lablab (2.86 kg ha^{-1} hr^{-1} CO_2-C) and 31 % lower than in finger millet (2.87 kg ha^{-1} hr^{-1} CO_2-C). In rainfed maize soil respiration was 0.3 % higher than in irrigated maize (2.19 kg ha^{-1} hr^{-1} CO_2-C) and rainfed finger millet had 1.6 % lower values than irrigated finger millet (2.87 kg ha^{-1} hr^{-1} CO_2-C). Under rainfed conditions high N maize plots had 94 % higher CO_2 fluxes than maize without N (1.48 kg ha^{-1} hr^{-1} CO_2-C). Similarly, in rainfed finger millet, CO_2 emissions on high N plots were 30 % higher than on controls (2.47 kg ha^{-1} hr^{-1} CO_2-C). During the Rabi season flux rates did not significantly differ between chili, cabbage and eggplant across fertiliser rates.

The results indicate that crop-specific CO_2 fluxes were independent of N fertilisation under irrigation, but were remarkably consistent across years. Under rainfed conditions CO_2 emissions on high N plots were significantly higher than on plots without N.

Keywords: CO_2 flux, fertiliser, multi-gas analyser, seasonal CO_2 emissions

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Increased fulvic acid concentration explains aggregate-associated carbon and nitrogen accumulation in a biochar-amended tropical soil

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Humic substances contribute largely to C and N sequestration by enhancing the accumulation of aggregate-associated C and N. However, the response of humic substances and aggregate-associated C and N to biochar application is less studied in the tropical ecosystem. A field experiment was conducted to investigate the effects of corn cob biochar on aggregate stability and humic substances, and how these humic substances impact on aggregate-associated C and N in a tropical ecosystem. The treatments included control/no biochar (CT), 15-ton biochar ha^{-1} (BC-15), 30-ton biochar ha^{-1} (BC-30), and 30-ton corn cob biochar ha^{-1} + phosphate fertiliser (BC-30 + P). The BC-30 and BC-30+P plots significantly increased the concentrations of the humic substances (humic and fulvic acids) compared to the CT. There was a significant increase in the mean weight diameter by 153 and 288 % in the BC-30 and BC-30+P treated soils was recorded. The BC-30 treatment resulted in a significant increase in the structural coefficient by 215 and 274 %, respectively, in the BC-30 and BC-30+P treatments relative to the CT. Significant increases in the aggregate-associated C and N accumulation were observed in the macro aggregates of the biochar-treated soils. The most important soil property that greatly contributed to the accumulation of aggregate-associated C and N was the fulvic acid – C, and, therefore, it could be used as an indicator to detect early accumulation of C and N in larger aggregates of soils of the humid tropics. Though the applied biochar increased the aliphatic and aromatic C compounds, it is the aliphatic C compound (fulvic acid) that largely and most significantly influenced early C and N accumulation within the macro aggregates in the shortest time.

Keywords: C and N stoichiometry, degree of polymerisation, geometric mean weight diameter, humic acid, humic substances, structural coefficient

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Does biochar application increase growth parameters and biomass of Jambú (*Acmella oleracea*) in Belém - Brazil?

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Jambú (*Acmella oleracea*) is a leafy vegetable of cultural and economic relevance in the Brazilian Amazon. With increasing demand, jambú cultivation represents an important source of income for small vegetable producers in the region of Belém. There is still a considerable lack of research about jambú cultivation and production potential in humid tropical conditions. In the region of Belém, soils are predominantly sandy and acidic. Daily heavy rainfalls lead to high leaching and nutrient losses, requiring constant fertiliser application. Fertiliser purchase is a significant cost in vegetable production and a limiting production factor for low-income smallholders. Alternatively, biochar is a soil amendment with the potential to retain nutrients and, increase the pH of soils. This study investigates the effects of biochar amendment on the growth parameters and development of Jambú in Belém. Two pot trials were executed in a randomised block design with six replicates for each treatment. Biochar was produced from coconut shell and bamboo (*Dendrocalamus giganteus*) in a conical earth pit. In the first pot trial, biochar treatment (3 g per kg soil) was combined with different doses of chicken manure (0, 6, 12 g per kg soil). In the second experiment, doses of biochar (0 g, 1 g, 3 g, and 5 g per kg soil) were combined with the same amount of chicken manure (12 g per kg soil) on two different soils (soil from fallow land and soil from a vegetable production area with intensive compost applications). Preliminary results of the first experiment show a slightly positive effect of the biochar treatments on plant growth and biomass of jambú compared to the treatments with only chicken manure. In the second trial, a slight increase in fresh and dry biomass could be observed for biochar treatments on soil from fallow land but no difference for biomass was observed for the farmland soil. This could be due to the fact that the farmland soil had a higher pH value (6.2) and was richer in nutrients than the soil from fallow land (4.1). Concluding biochar application might increase jambú production on marginal land but does not impact production on more fertile soils.

Keywords: *Acmella oleracea*, Amazon, Belém, biochar, jambu, Pará, smallholders, vegetable production

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Microbial dynamics in hierarchical aggregates of tropical soil amended with bambara groundnut seed residue biochar

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Application of bambara groundnut seed residue biochar (BSB) in vegetable production has shown to affect soil fertility, especially carbon (C) and nitrogen (N). However, there is a lack of knowledge on the microbial responses to repeated applications of BSB and NPK fertilisers in different soil aggregates. For this purpose, three replicates of four-treated soil samples (control, NPK, BSB, and NPK+BSB) arranged in Randomised Complete Block Design were taken after four years of continuous cultivation of cucumber crops at Nsukka Nigeria. The samples were mechanically separated into four dry-stable aggregate fractions of 4.75–2.00, 1.00–2.00, < 0.25–1.00, and < 0.25 mm. In addition to bulk soil < 2.00 mm, these five soil aggregate hierarchies were evaluated, with the aim of determining the effect of treatments on soil microbial nutrient cycling in a 20-day incubation experiment. The cumulative CO_2 emission in soil hierarchies at day 20 was relatively low in the control and BSB soils, ranging from 0.10 to 0.21 and 0.14 to 0.26 mg CO_2-C soil^{-1}, respectively. In general, increased labile C utilisation was significantly higher in the < 0.25 mm aggregate than in other soil fractions in all the amended soils. Nonetheless, cumulative CO_2 respiration in all the soil hierarchies increased significantly in the NPK and NPK+BSB amended soils compared to the BSB and control soils. There is a small pool of labile C that explains the insignificant effect of the BSB application on the basal respiration of the soil aggregates. The NPK+BSB amendment increased microbial C in 1.00–2.00 mm aggregate and < 2.00 mm soil by 40 % and 70 %, respectively, and microbial biomass N in 4.75–2.00 and 1.00–2.00 mm aggregates, and in < 2.00 mm soil by 106 %, 89 % and 341 %, respectively. The β-glucosidase activity was significantly reduced in the NPK and NPK + BSB amended soils compared to the BSB soil, whereas the reverse was the case with the reduced N-acetyl-β-glucosaminidase enzyme. Increased tyrosine aminopeptidase enzyme activity was evident in the NPK and NPK+BSB amended soils and in all aggregate hierarchies, but the C-cycle enzyme activities were mostly maximal in the < 0.25 mm aggregate fraction. The study highlights that NPK+BSB amendment can induce greater C mineralisation in < 0.25 mm aggregate fractions. Moreover, the substantial increase in microbial C and N with the NPK+BSB amendment indicates the significant association of the > 1.00 mm macro-aggregates to the improvement of soil quality.

Keywords: Biochar amendment, C mineralisation, dry-stable aggregates, enzyme activity, microbial biomass

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Impact of land use on soil physicochemical properties in the semiarid climate zone in Benin (West Africa)

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In Benin, a West African country, land and soil degradation affect the livelihood of the local population mainly in the semiarid climate zone where intensive cash crop production is the dominant land use. Natural vegetation with non-degraded soils may provide a benchmark to evaluate the status of soil degradation in different cropping systems. In the present study we therefore compared topsoil at 0–10 cm depth from different food crops (cereals and legumes) and cash crops (cotton) with natural vegetation (woodland) for differences in physicochemical soil properties such as particle size distribution, bulk density, pH, electrical conductivity (EC), water stable aggregates (WSA), water holding capacity (WHC), total soil nitrogen (N), soil organic carbon (SOC) and total soil sulfur. The findings revealed no significant differences between land use in the physicochemical properties except for bulk density (BD) which was significantly higher in cropped fields (1.44 ± 0.01–1.58 ± 0.02) except for cotton (1.34 ± 0.01) and peanut (1.35 ± 0.02), compared to woodland (1.40 ± 0.02). The C/N ratio was significantly lower in cropped fields (7.06 ± 4.05 – 11.14 ± 1.47) than in woodland (14.54 ± 2.91). The pH (H_2O) of the cropped fields was mildly acidic (6.22 ± 0.10 – 6.55 ± 0.22) as compared to woodland (7.14 ± 0.78) except for sorghum-millet fields (7.20 ± 0.41). The EC and WSA were low in crops fields particularly the cotton fields (18.63 ± 0.52 μS/cm for EC and 68.70 ± 0.61 % for WSA) compared to woodland (56.30 ± 46.53 μs/cm for EC and 89.95 ± 7.60 % for WSA). WHC was higher in crop fields (28.77 ± 2.97–32.20 ± 0.84 %) except cotton (27.47 ± 0.83 %) compared to woodland (28.71 ± 2.93 %). Total N and SOC were low in crop fields particularly in peanut fields.

Keywords: Cotton, ferruginous soils, land use, soil degradation, West Africa

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Soil nutrient distribution and soil carbon stocks in pigeon peas growing areas in Lindi, Tanzania

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Pigeon peas are a key legume crop contributing to dietary needs and economic livelihood of smallholder farmers in Tanzania. Soil organic carbon stocks facilitate the sustainability of the crop production system. The aim of this study was to assess soil nutrient content and soil organic carbon (SOC) stocks in selected pigeon pea growing areas in Lindi, Tanzania. Bulk soil samples were taken at 0–30 cm depth from 22 pigeon pea farms in two districts – Nachingwea and Ruangwa. Soil samples were analysed for soil-physicochemical properties (pH, Clay and Silt) and nutrient content (nitrogen (N), phosphorus (P) and potassium (K)). Soil organic carbon stocks were calculated following Zeng et al. (2021). Bulk density was estimated using a pedotransfer function. Inverse distance weighing was used to generate the maps of soil Nutrients (NPK) and SOC stocks. All sampled PP farms were intercropped with maize and had no fertiliser amendments. Most of the sampled soils in the study areas were of sandy clay loam texture. The mean nitrogen, phosphorus and potassium content was 0.1 %, 31.4 mg kg^{-1}, 225 mg kg^{-1} respectively. Mean organic carbon was 1.4 % while mean SOC stocks were 504.6 g m^{-2}. Mean clay, silt and sand content were 29.6 %, 2.8 % and 67.6 %. Nutrient contents and SOC stocks were generally higher for Nachingwea than Ruangwa district. Results indicate that mean nitrogen content was beyond the optimal range, while phosphorus and potassium contents were high. The N-fixing capability of pigeon peas enhances the supply of nitrogen in the production system. Intercropping pigeon peas with major food crops is essential for this farming system to maintain the nutrient balance required to sustain production of crops for dietary supply without fertilisers.

Keywords: Pigeon peas, soil nutrients, soil organic carbon stocks

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Soil-specific responses of methanotrophic communities in the rice rhizosphere to genotype and nitrogen fertilisation

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One of the most significant agricultural sources of the greenhouse gas methane is lowland rice production. An approach to reduce methane flux from the rice field is to develop rice varieties that support methane oxidation in the roots and surrounding rhizosphere by methanotrophs. However, the effect of different genotypes on methanotrophic communities in comparison to other influence factors such as soil or nitrogen fertilisation management is still poorly understood. We conducted *pmoA* amplicon sequencing of root and rhizosphere samples collected from planted (Kasalath, Nipponbare, IR64, and *O. rufipogon*) and unplanted (as a control) paddy soil microcosms. The microcosms contained either Italian or Philippine paddy soil and were either fertilised with additional N ($50\,kg\,ha^{-1}$) or not. 2,865 amplicon sequence variants were identified across 171 samples. Compositional analysis showed that *Methylocystis* sp. dominated in the Italian paddy soil, while *Methylococcus* sp. and uncultured rice paddy clusters were more commonly detected in the Philippine soil. Beta diversity analysis based on Aitchison distance and PERMANOVA showed that the two soils had significantly different (R^2=0.332, P = .001) methanotrophic communities. On a per soil basis, the effect of genotype was significant in Philippine soil (R^2=0.082, P = .001) where Kasalath had a similar community with Nipponbare, but different to *O. rufipogon*. In the Italian soil, the fertilisation schemes (R^2=0.025, P = .004) and genotypes (R^2=0.064, P = .004) resulted in significantly different methanotrophic communities, with Kasalath and Nipponbare hosting similar communities, especially in the root compartment. Our findings indicate that community assembly of methanotrophs in the rice root and rhizosphere depends on the native population present in the soil and that plant-genotype effects and nitrogen fertilisation-responses are soil specific. Despite being phylogenetically distant, i.e. Nipponbare to Kasalath, they established similar methanotrophic communities, which indicates that the relatedness of the genotypes is not necessarily reflected in the preferential recruitment of dis-/similar methanotrophic communities.

Keywords: Greenhouse gas, methane, methanotrophs, microcosm, PmoA, rhizosphere, rice, rice variety

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Mapping the distribution of saline water below rice production systems in the Vietnam Mekong Delta by applying geophysical methods

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The Vietnam Mekong Delta (VMD), home of over 20 million of people, where rice is a staple crop contributing more than half the rice production of the whole country. However, climate change, decreased river flow and land subsidence are leading to saltwater intrusion, which poses a significant threat to rice production in the delta. Soil salinity can be caused by seawater either intruding through tidal movements into the irrigation canal system or via seepage into near surface water tables from where it can intrude into paddy fields via capillary rise during dry season. In order to develop appropriate management strategies for the adaptation of rice production systems in the Mekong Delta to the increasing threat of soil salinisation, it is important to understand the spatial distribution of top soil salinity and the saline aquifers below rice production areas. The distribution of subsurface salinity was investigated by using integrated electrical methods, including Electrical Resistivity Tomography (ARES II) and Electromagnetic Induction Measurement (EM38). Top soil and sub-soil salinity of profiles approximately 300 m in length were measured at 40 locations following geological transects which illustrate salinity gradients in this case study in the VMD. The resulting resistivity profiles were interpreted via boreholes information available in the study area. Preliminary results show there is a dissimilarity in the distribution of salinity between top soil and sub-soil layers in the rice production system. Increased top-soil salinity was mainly observed in the centre of the study area, probably introduced via irrigation whereas salinity in the sub-soil layers increased with proximity to the saltwater sources. A potential link between the distribution of soil salinity, land-use, and salinity level of surface water will be discussed.

Keywords: Electrical conductivity, electrical resistivity tomography, shallow groundwater

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Soil improvement in Ethiopia through the energetic and material use of agricultural residues, ETH-soil

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Soils are a fundamental natural resource and the basis for all life on land. Several environmental or anthropogenic influences can lead to a deterioration of the physical, chemical and biological conditions of soil quality, which leads to food insecurity especially for the most vulnerable groups of societies. The ËTH-Soilproject (07/2021–12/2026) aims to significantly improve food security in three Ethiopian pilot regions in the Oromia region through the application of an organic fertiliser produced from pyrolysis and biogas plants. The process to be used combines biochar with digestate from biogas plants or compost material to create a fertiliser for soil improvement in order to effectively utilise the advantages of both feedstocks. The application of a combined organic fertiliser aims to improve degraded farmland and elevate yields. Main target groups are small and micro farmers in rural areas with low income and food shortage as well as users and consumers of bioenergy, such as pyrolysis and biogas and their products. Another essential factor in ensuring the sustainability of the project is the participatory further development of a pyrolysis cook stove as well as the implementation of several trainings and further education of specialists for an economic, social and technical progress. Following this approach, the project makes a significant contribution to the national implementation of the Agenda 2030 and addresses solutions to combating hunger through untapped agricultural and social potential, sustainable management of natural resources, and education and training for economic, social and technical progress. The project has been commissioned by the German Federal Ministry for Economic Cooperation and Development (BMZ).

Keywords: Biochar, climate smart, soil, sustainability

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Soils of lower Moshi irrigation scheme, northeastern Tanzania: their implications for agricultural land management

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A standard soil survey was conducted in lower Moshi irrigation scheme, Tanzania to investigate the soils and their implications for agricultural land management. It has been operational since 1987 and produces a considerable amount of rice for the natives of Kilimanjaro, Tanzania, and Kenya. These soils have never been studied since the scheme became in operation. Soil morphological and physico-chemical properties were studied in three soil pits dug to a depth of 150 cm. Bulk samples were taken in triplicate at the depth of 0–20 cm on-farm plots under continuous irrigated rice, irrigated maize rotation, and rainfed maize for soil fertility characterisation. Two-way ANOVA was conducted to test the significance of site and treatment. Soils were classified according to the World Reference Base for Soil Resources (WRB). They are fine-textured (clayey) developed from young fluvial-volcanic deposits. The three soil profiles analysed comprise the following: : (1) deep, well-drained very dark grayish brown, clayey soil over a layer of gravel and brittle pumice or tuffite below a depth of 110 cm in the rainfed maize; (2) Deep, well-drained, brown sand clay loam over a layer of massive gravel and murram below a depth of 90 cm in the maize-rice rotation; and (3) Very deep, well-drained reddish-brown clayey soil over a layer of unconsolidated gravel below a depth of 150 cm under continuous paddy farming. These soils were classified as Eutric Cambisols. Although the studied soils portray an impression of good fertility, they are characterised by the following problems: low soil fertility as shown by low organic carbon ($< 1.0\,\%$), low levels of major nutrients (nitrogen $<0.1\,\%$ and phosphorus < 1 mg P/kg). The soils under Maize-rice rotation have unfavourable Mg/K ratios of > 7 below a depth of 25 cm. pH values of the topsoil (0–20 cm) were significantly higher ($p = 0.1$) for maize-rice rotation farm plots than continuous paddy farming plots. The results obtained in this study should therefore be considered for guiding sustainable agricultural management of the scheme. This includes the application and management of fertilisers; their interaction and their effect on crop performance.

Keywords: Agricultural land management, irrigation scheme, soil management

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Respiration and priming effect in different land use types in semi-arid area of northern Ethiopia

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Addition of easily available carbon (C) sources increases soil microbial activity, often resulting in priming effects (PEs) - short-term changes in soil organic matter (SOM) decomposition following substrate addition. Land use and agricultural management practices exert profound control on SOM turnover and its interactions with the global C cycle through different mechanisms. In this study, respiration and PE were quantified in soils sampled from four contrasting land uses (forest, exclosure, grazing and cultivated land) in four locations, across three layers (0–30, 30–60 and 60–90 cm) in a semi-arid area of northern Ethiopia. We hypothesised that land use might affect SOM turnover through changes in C input rates, nutrient availability, and PEs. Soils were incubated for 23 days and PE and respiration quantified after addition of 14C labeled glucose corresponding to 50 % of initial microbial biomass carbon (MBC). Generally, application of substrate to the soil stimulated production of CO_2 in all land use types. The CO_2 respired was 30–63 % lower in sub than in topsoil with most expressed depth gradients in croplands. In subsoil, the weak negative PEs is an indication of highly stabilised C. Contrary, glucose addition induced stronger positive PEs in topsoils sampled from forest, exclosure and grazing land. The temporal dynamics of PEs involved a strong positive peak for the first five days after glucose addition and a second smaller peak 10 days after glucose addition in natural ecosystem, corresponding to apparent and real PE, respectively. Lack of positive correlation between PEs and C/N ratio ruled out the N-mining hypothesis, but a positive correlation between PE and MBC suggests co-metabolism as possible mechanism behind the real PE. Higher priming in natural ecosystem compared to cropland is an indication that conversion of natural ecosystem to continuous cropping system leads to depletion of the primable C pool in dryland soils. Additionally, this land use conversion negatively affects biogeochemical C cycling by an altered response of soil microbes to C input.

Keywords: Glucose, drylands, land use, mineralisation, soil organic matter

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Soil loss reduction and rainwater management in climate smart maize and coffee production systems

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Adequate rainwater management at the field level is an important measure to increase the resilience of agriculture to the effects of climate change. The implementation of soil and water conservation practices can significantly reduce erosion, increase the amount of plants available soil water, and mitigate the effects of intra-seasonal dry periods. The ALRI-RAICES project began measuring soil loss and runoff in maize and coffee production systems in 2021 in the department of Ahuachapan, El Salvador. Three erosion measurement plots were established at each of the two sites in San Raymundo (maize) and Apaneca (coffee) with the following characteristics: bare fallow (SR1 and AP1), conventional maize (SR2), maize with mulch (SR3), shaded coffee (AP2), and shaded coffee with vegetative barriers of Vetiver and cover crop (AP3). During the measurement period between May and October, 1204 mm of rainfall was recorded in San Raymundo and 2197 mm in Apaneca. Measured soil erosion and surface runoff varied significantly among the different plots. In the conventional maize plot, 94.6 t ha^{-1} soil loss was measured, of which 86 % was due to six heavy erosive rains at the beginning of the rainy season and in the early stage of crop development in May and June. In comparison, mulching was a very efficient measure to reduce soil loss to only 1.2 t ha^{-1}. In addition, 143.8 mm more rainwater was absorbed and infiltrated on the SR3 plot than on the SR2, equivalent to 1490 cubic meters per hectare, which demonstrates the importance of ground cover for in-field water management. In both coffee plots, only a single rainfall event of 245 mm triggered low soil loss of 0.02 (AP2) and 0.1 t ha^{-1} (AP3). The implemented soil protection measures had no additional effect under the given conditions. Coffee cultivation in the shade cropping system with multi-stratified vegetation cover and advantageous soil properties created a resilient system that provides high hydrological services. The two bare fallow plots (SR1, AP1) showed significant differences in runoff development and erosion resistance, highlighting the importance of soil properties in the erosion process and for field water management.

Keywords: Cover crops, erosion measurement, in-field rainwater harvesting

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Review on the sustainability of irrigation dam projects and agriculture water use efficiency problems in Ethiopia

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Water is the central issue for achieving the overall Sustainable Development Goals (SDGs). Ethiopia is constructing large, medium, and small scale dams or reservoirs for irrigation practices to enhance the production and productivity of agriculture. However, the constructed irrigation dams are not working properly as expected of the estimation of their life span. Thus, the aim of this systematic review is that identifying the drivers that are influencing the functionality of the irrigation dams in its economic perspective, agriculture water use efficiency, and pointing out the possible suggestions for the government to improve the agriculture water use efficiency and keep the sustainability of the economic value of the constructed irrigation dams. This paper revealed that farmers cannot outshine from their subsistence farming even though they have been practicing irrigation for a long time. Additionally, this review showed that the challenges that hinder the constructed irrigation dam functionality includes high level of sediment, poor water and soil conservation practices in the upper level of the dams, farmers lack of knowledge on the use of irrigation technologies/ structures, damage canals or deterioration of irrigation structures, and faces tragedy of common (no responsible body for managing the irrigation dam after construction). The problems in the perspective of agriculture water use efficiency includes mismanagement of irrigation or water extravagancy, lack of knowledge on irrigation use and maintenance, lack of research on crop-specific water demand, waterlogging problems, and improper irrigation schedule. To achieve agriculture water use efficiency, the combination of water-efficient technologies and incentives for proper use and conservation of the irrigation schemes and dams to be required. Thus, the systematic review will provide decision makers with effective regulations to manage water use and allocation, enhance the attitude of the communities, mobilise the community to adopt soil and water conservation practices to reduce the level of sediment and keep the sustainability of the irrigation dam and lead to increase in agriculture water use efficiency.

Keywords: Ethiopia, irrigation dam, sustainability, water use efficiency

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Biochar improved gravelly soil water and fertiliser use efficiency and the yield of pearl millet (*Pennisetum glaucum*)

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The effect of biochar on water and fertiliser use and the response of pearl millet(*Pennisetum glaucum*) grown on a gravelly soil (> 15 % v/v) of Northern Ghana was investigated in a greenhouse. Gravelly soil with varying soil gravel contents (SGC) of 0 %, 10 %, 30 %, 40 % and 60 % were constructed with Polyvinyl chloride columns (internal diameter = 16 cm and height= 40 cm). Rice husk biochar (pyrolyzed at 360°C) was applied at 25 ton ha^{-1} in three application modes: no biochar (BCN_m), top 10 cm mix (BCT_m) and fully mixed (BCF_m). These columns were randomly arranged in the greenhouse, pearl millet seeded and fertilised at 100 kg N ha^{-1}, 40 kg P ha^{-1} and 40 kg K ha^{-1}. Rainfall was simulated following normal rainfall patterns for the soil sampling area, derived from 42-year rainfall data. Runoff (R) and drainage (D) were determined following each simulated rainfall event, whiles the soil moisture content (θ) was determined as the difference in moisture before and after irrigation. The actual evapotranspiration (ET_a) was calculated using the water balance equation. Plant growth data collected were plant height, number of tillers, leaves and chlorophyll content. The water use efficiency (WUE) was determined as the ratio of grain yield to the ET_a. The partial factor productivity (PFP) was determined as the ratio of the plant shoot and grain weight to the N applied. The results showed that biochar significantly increased the θ and reduced (R + D) by 35 and 32% for BCT_m and BCF_m compared to BCN_m, respectively. Biochar reduced ($p < 0.05$) nutrient loss in soils containing ≤ 40 % SGCs. The plant growth parameters responded positively to the biochar amended soil and consequently reduced the negative effects of SGC on plant development. The WUE and PFP in the gravelly soils increased with biochar addition even at 60 % SGC compared to the BCN_m. Biochar application (BCT_m and BCF_m) resulted in increased θ, grain yield WUE and PFP than the BCN_m. In conclusion, biochar improved θ by filling the macropores created by soil gravels, increased soil CEC and P status, thus, increased yield, the highest effect measured at BCF_m.

Keywords: Biochar, nutrient loss, soil gravel content, water balance components, water use efficiency

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Intra-seasonal variability of soil chemical properties in paddy cultivation: a case study from Sri Lanka

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Supplementing plant nutrients through fertiliser plays an important role in increasing the soil's capacity to produce greater quantities of high-quality food. Improper use and management of nutrients may lead to adverse impacts on the environment, negative cost-effectiveness of fertiliser applications as well as reduced yield of plants. Assessment of soil chemical properties is important to conserve soil health and fertility. The objective of this study was to investigate differences in the soil's chemical properties in the cropping cycle of paddy cultivation which use different organic fertilisers. So, this study was conducted to explore the variability of agronomically important soil chemical properties of paddy growing areas in Polonnaruwa district (Mahaweli system B) of Sri Lanka. Soil samples were taken from selected blocks prior to ploughing, just after establishment, end of the vegetative stage, just before the booting stage, and at the maturity stage. Soil chemical properties namely, soil organic matter, available Phosphorus, exchangeable Potassium, pH and electrical conductivity were tested in two depth (0–5 cm and 5 – 15 cm) intervals. Results revealed that all tested soil chemical properties varied with the cropping cycle of each block. Soil organic matter, available Phosphorus and exchangeable Potassium also varied along the two-depth interval while pH and electrical conductivity did not vary among the two depths. In all blocks, the highest available Phosphorus, exchangeable Potassium and pH were recorded prior to ploughing while the highest soil organic matter and electrical conductivity were recorded just after establishment. The lowest soil organic matter, available Phosphorus, exchangeable Potassium and pH were recorded at the maturity stage in all blocks. The observed soil property dependencies can be utilised to fine-tune fertiliser application schemes, irrigation, and tillage operations at the field level to enhance rice crop yield while avoiding negative environmental effects.

Keywords: Chemical properties, cropping cycle, paddy cultivation, variability

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Quality and fertility assessments of compost produced from cleaner development mechanism projects: a case of Uganda

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Despite the fact that compost projects under the Cleaner Development Mechanism (CDM) have been implemented in sub-Saharan Africa in recent years, there is a paucity of information on the quality of compost produced from the compost plants. This study fills this gap by evaluating the properties of MSWC produced from 12 CDM plants in Uganda based on quality and fertilising indices. pH, Pb N, K, P, Mn, Cd, Ca, Mg, Cu, Fe, Cr, Zn, OC, and CN levels differed significantly between locations. MSWC's Fertility Indices (FI) ranged from 1.9 to 2.9, with Mbarara having the highest (2.9) and Soroti having the lowest (1.9). Fort Portal, Mbarara, Kasese, and Masindi have Clean Indices (CI) ranging from 3.8 to 4.9. According to the results of the fertility and Clean Indices analysis, all MSW composts generated at CDM facilities have low fertilising capacity and poor quality and are classified as Class RU^{-1}, which does not meet international and national compost criteria. As a result, these composts cannot be utilised as fertilisers and can only be used as soil conditioners under certain conditions. Windrow composting has been proven to be a viable method for lowering huge amounts of organic municipal solid waste in urban areas, and it can be scaled up to other parts of the world according to this study. Authorities must, however, engage urban citizens in waste separation at the source and MSWC enrichment with organic sources. This will aid in improving its quality and fertilising capacity, as well as in ensuring that the MSWC produced is uniform and suited for use in agriculture and the market.

Keywords: Clean index, composting, fertility index, organic wastes, soil conditioners

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Effect of soil management practices on soil carbon dynamics under maize cultivation

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An increasing world population and change in consumer preferences necessitate the need to increase food production to meet the demand of a changing world. Intensified agriculture and an accelerated climate crisis with increasing weather extremes threaten the resource base needed to improve crop production. Maize yield obtained by farmers in the guinea savannah zone of Ghana is generally low due to low soil fertility status resulting from continuous cropping coupled with low use of external inputs. Integrated Soil Fertility Management (ISFM) practices have proven to sustainably increase maize yield. However, majority of the farmers practicing ISFM till their land conventionally, potentially resulting in substantial greenhouse gases (GHG) emissions that contribute to global climate change. However, there is dearth of information on GHG emissions regarding crop production systems in sub-Saharan Africa in general and Ghana in particular. Hence, within a field trial we seek to investigate the impact of different tillage practices and ISFM applied to sustain maize yield, on net CO_2 or ecosystem exchange (NEE) and net carbon (C) balance (NECB). The field trial was established in Northern region of Ghana. A split plot design was used with the main plot treatments being conventional tillage and reduced tillage and the subplot treatments being factorial combination of organic and inorganic fertilisers at three levels each. To determine NEE and thereon based estimates of NECB, an innovative, customized, low-cost manual, dynamic closed chamber system was used. CO_2 concentration increase and decrease over chamber deployment time was detected by portable, inexpensive Arduino based CO_2 logging systems, consisting of a battery powered microcontroller (Arduino Uno) con-

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nected to an NDIR-CO_2 sensor (SCD30; $\pm$ 30 ppm accuracy), air temperature and humidity (DHT-22) as well as air pressure sensor (BMP280). Measured CO_2 fluxes were subsequently gap-filled to obtain seasonal NEE. C import and export were further on added to NEE to determine the NECB for each treatment. In parallel to CO_2 exchange measurement campaigns, agronomic and crop growth indices such as the normalised difference vegetation index were performed biweekly at all plots. Here we present NEE and NECB balances for the first crop growth period.

Keywords: CO_2 emission, integrated soil fertility management, net ecosystem carbon balance, tillage, *Zea mays*

Microbial community, biomass and physico-chemical properties of soil in dry tropics

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Soil physicochemical and microbial properties can be regarded as an important tool to assess soil quality and health. Studying the soil properties under different land use types is of great practical significance for land use and soil management regarding soil carbon dynamics and climate change mitigation. However, the changes in land use types and their effects on soil physicochemical and microbial properties are largely debated and rather unclear. Four different land use types were used to study soil microbial and soil physicochemical properties. Soil organic carbon and total nitrogen, soil microbial biomass, and microbial diversity were determined by micro-kjeldahl method, fumigation and extraction method, and FAME GC-Ms, respectively.
Among all land use patterns, the highest water holding capacity (40.06 ± 0.74 %), porosity (0.539 ± 0.011 %), soil macro-aggregates (64.16 ± 2.64 %), organic carbon (0.84 ± 0.054 %), total nitrogen (0.123 ± 0.013 %), microbial biomass carbon (570.65 ± 35.05 $\mu g\, g^{-1}$) and nitrogen (84.21 ± 3.186 $\mu g\, g^{-1}$), basal respiration (3.64 ± 0.064 $\mu g\, g^{-1}$) and b-glucosidase (809.68 ± 39.7 μg PNP g^{-1} dry soil h^{-1}) were found to be under natural forest followed by, in decreasing order, bamboo plantation, degraded forest, and agricultural land. Significant differences were observed among the land use types in microbial biomass carbon and B-glucosidase activity. Furthermore, the correlation analysis showed that microbial biomass, organic carbon, b-glucosidas activity, total nitrogen, moisture content, porosity, water holding capacity, and soil macroaggregates were positively correlated with each other and negatively correlated to bulk density, meso and micro-soil aggregates at $p < 0.05$. The PLFA analysis showed that microbial community diversity exhibited distinct patterns among land-use types. With the conversion of natural forest to other land use types, the amount of PLFA were reduced significantly. The natural forest had high microbial diversity followed by in decreasing order bamboo plantations, degraded forest, and agricultural land. Among the organisms G- bacteria and fungi were showed decreasing order from natural forest, bamboo plantation, degraded forest, and agricultural land. The reverse was true for G+ bacteria. The results of this study showed that soil physico-chemical and microbial properties were significantly affected by land use types. Thus, bamboo-based fallow has the potential for improving soil quality and properties in the short term.

Keywords: Land use type, microbial biomass, microbial soil diversity, soil physico-chemical properties

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Effect of N fertiliser amount and water management on CO_2 exchange and net ecosystem C balance of rice cultivation in southern Benin

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Application of mineral nitrogen (N) fertiliser and water management are two very essential farming practices, used to optimise potential yields in sub-Sahara African rice cultivation. Differences in both practices, however, might affect the patterns of climate relevant gaseous carbon (C) emissions (CO_2 and CH_4) and soil C losses, thus contributing to global climate change. To date, knowledge about the combined effects of different N fertiliser rates together with different water management practices on the gaseous C emissions and soil C losses are very limited. Our study aims to identify the best combination of water management and N fertiliser amount to reduce gaseous C emissions and limit soil C losses for an irrigated rice production in Benin. We hypothesise that especially a combination of alternate wetting and drying (AWD) as water management and an optimum amount of N fertiliser reduce gaseous C emissions and might help to enhance C sequestration by reducing soil C losses from irrigated rice production in Benin. To test this hypothesis, a field experiment was established at Koussin lélé, Cove district, southern Benin using a full factorial, split-plot experimental design. Within the experiment the combination of three levels of water management and two levels of N fertiliser amount are tested. The water management technologies include continuous flooding (CF) and two alternate wetting and drying (AWD) methods (AWD15 and AWD25) of irrigation. Nitrogen fertiliser levels is 90 kg ha^{-1} (farmer's practice) and 120 kg ha^{-1}. To measure gaseous C emissions (CO_2 and CH_4) and estimate dynamics in soil C losses, an in-

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novative, customized low cost dynamic NFT-NSS closed chamber system is used. The system consists of CO_2/CH_4 NDIR sensors connected to a microcontroller for data storage and transparent (NEE measurements) polycarbonate chambers (40 cm × 40 cm × 100 cm). To measure Reco, transparent chambers were covered with an opaque hood. Chamber measurements for diurnal variability in CH_4 and CO_2 fluxes are performed biweekly at all plots. In addition, agronomy and crop growth indices such as the Normalized difference vegetation index (NDVI) are measured weekly. Here we present CO_2 and NECB balances for the first crop growth period.

Keywords: CO_2 emission, N fertiliser, net ecosystem carbon balance (NECB), rice, water management

Interactive effect of biochar and PVC microplastic on soil microbes and enzyme activity

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Plastic pollution is one of the most pressing issues of the growing population and their lifestyle. Polyvinyl chloride (PVC) is one of the most toxic and abundant microplastics (MPs, <5mm) found in sludge and ultimately in agricultural soils. PVC and other MPs pollution have shown serious concerns on ecosystem services. However, the investigations on PVC and biochar (the so-called pro-ecosystem technology) under the real soil-plant system are seriously lacking. Hereby, we investigated the impact of PVC-MPs (0, 0.25 % and 0.5 %, (w/w)) with and without a cotton stalk (*Gossipium hirsutum* L.) biochar (0.5 % (w/w)) on soil biological diversity, organic carbon, nitrogen, and enzymes activities within a soil-plant system. PVC-MPs had shown a negative, dose-dependent impact on soil nutrient and enzyme activities thereby reducing overall microbial communities (-60.13 %). However, biochar addition significantly alleviated the hazardous effects of PVC-MPs. Biochar addition improved soil carbon, nitrogen, dehydrogenase, and urease activity. Improved soil conditions resulted in improved microbial abundance by +61.27 %, as indicated by PLFAs biomarkers, except for gram-positive bacteria. The principal component and redundancy analysis of the soil properties, bacterial 16S rRNA gene, and fungal ITS in the biochar amended PVC-MPs treatments revealed that the observed traits formed an obvious cluster. In conclusion, the PVC-MPs contamination in a soil-plant system was not benign while the presence of biochar shielded the toxic effects and sustained ecosystem services. It thus warrants further studies till the maturity of crops to elucidate the MP's effects on crop production and their suspected transfer into the food chain.

Keywords: Biochar, enzymes, microbiome, microplastics

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Agricultural adaptation in the face of climate change

Loosing value: how climate change impacts agricultural value chains in Uganda

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Climate change increasingly causes challenges for agricultural systems and poses a serious threat to people whose livelihoods depend on agriculture. So far, climate risk assessments, both quantitative and qualitative, often only focus on the production stage of agricultural value chains, failing to consider other steps, such as processing, aggregation, marketing and transport, which are equally important for household income and therefore essential to consider when designing climate change adaptation strategies.

Value chain analysis has become a useful and often applied tool to assess the complex relationships of value chain steps (production, processing, aggregation, marketing and transport) within agricultural systems, but rarely considers climate change. In this study, we examine climate change impacts on coffee and maize value chains in Central and Northern Uganda. Through a set of 19 focus group discussion and 14 interviews with actors along the maize and coffee value chains we analyse which climate impacts are most commonly experienced at the different steps of the selected value chains. The qualitative assessment is complemented with quantitative climate impact and crop modelling to add an important contextual layer to our understanding of climate impacts on key commodity value chains.

Results show that all steps of the value chain are exposed to adverse effect of climate change with strong feedback loops between the different steps. In particular, climate change impacts on crop production can already be felt and will further be influenced by climate change in entire Uganda. Impacts on production have considerable trickle-down effects on storage, processing and marketing, leading to losses in each step of the value chain. We also find that climate change influences the dynamics between the different actors and the systems they are embedded in.

The results of this study showcase the need to take into consideration the entire value chain when identifying adaptation strategies that help farmers build productive and resilient livelihoods. In addition, the study develops a framework for climate risk analyses of agricultural value chains by combining qualitative analysis with quantitative climate impact and crop modelling.

Keywords: Agriculture, climate change adaptation, coffee, maize, risk, value chain

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Developing a climate resilience index for cocoa farming households in Uganda

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Cocoa is a climate-sensitive crop with growing global demand. In Uganda, the climatic suitability for cocoa is projected to improve during climate change, yet Ugandan cocoa farmers are affected by adverse effects of climatic events. While past studies have developed frameworks to measure farms' climate resilience, no blueprint solution for all farming systems across the globe exists. The goals of this study are 1) to develop a climate resilience framework to assess the climate resilience of smallholder cocoa farms and 2) to implement and test the developed Climate Resilience Index (CRI) for a sample of cocoa farmers in Uganda.

The CRI quantifies climate resilience according to the three resilience capacities: short-term absorption, medium-term adaptation, and long-term transformation. Based on discussions with local experts on cocoa cultivation, existing climate resilience frameworks were adjusted and indicators revised to develop the CRI suiting the local context. Primary data from 203 households was used for the calculation of the CRI. First, responses of all 30 indicators were normalised and grouped by resilience capacity. We decided for an unequal, altered weighting approach of the indicators by applying a Principal Component Analysis for each resilience capacity. The scores of the first principal component, the means and standard deviations of each indicator were used to construct the CRI. We calculated the climate resilience scores for each farm per resilience capacity and an overall climate resilience score for every farm.

The results show the climate resilience of a cocoa farming household relative to the other households in the sample. 98.5 % of farmers reported to have experienced a climatic shock or stressor within the past 12 months, mostly unpredictable rainfall and shifted rainy seasons. We observed little variation in absorptive scores which illustrates farmers' similar capacities in absorbing minor short-term climatic shocks. Adaptive scores showed the highest discrepancy between farms, pointing out farmers broadly differing capacities regarding medium-term adaptation. Transformative scores displayed the least variability between farms and implies farmers' equal need for support regarding structural long-term transformation.

The framework and results can inform regional policy support to strengthen climate resilience for Ugandan smallholder cocoa farms.

Keywords: Climate change, climate resilience, cocoa, Uganda

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Status-quo of selected nationally determined contributions using spaceborne remote sensing – the case of West Africax

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With the nationally determined contributions (NDCs), Parties of the Paris Agreement keep hold of the policy goals and measurements, which they consider essential for their nations' climate action plan toward reducing emissions and building climate resilience. These NDCs must be communicated in a five-year cycle, which is an important step towards pushing ambitions and promoting transparent, evidence-based policy (EBP) making. Worldwide, governments use the EBP approach to shed light on policy impact, enhance policies' effectiveness and efficiency and promote policy coherence. Subsequently, EBP can be an important step toward tracking policy compliance, thus building trust and confidence among the parties involved in the Paris Agreement. Monitoring the implementation and effectiveness of the NDCs is essential for successful EBP and tracking the progress towards meeting the internationally determined objectives of the Paris Agreement. However, a critical barrier to EBP is the lack of a comprehensive, spatially explicit, neutral policy monitoring and evaluation – a process that often involves financial and personal resources. The latter can constitute a non-negligible hurdle for developing countries, such as West African (WA) countries. Space-borne remote sensing (RS) data provide valuable information about the physical earth's surface at different spatial and temporal scales and in an area-wide, systematic, and consistent manner. A further advantage lies in the availability of pre-processed RS products and information that can support decision-making, e.g., in land management. Further, products tailored explicitly to WA countries' needs (e.g., high-resolution vegetation structure and burnt area maps) are increasingly provided by regional research activities, such as led by the West African Science Service Centre on Climate Change and Adapted Land Use (WASCAL) and associated projects, such as the BMBF-funded WASCAL-DE-Coop. To this end, RS can be a valuable tool to complement monitoring systems in the realm of the Paris Agreement. The present contribution aims at providing insights into the status-quo of WA countries regarding selected land-use related NDC goals in the agricultural and forest sector from an RS perspective. In this context, this study discusses potential conflicts between selected goals and provides insights into the capabilities and limitations of RS in the realm of the analysis.

Keywords: Earth observation, evidence-based policy, Paris agreement

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Applying intersectional perspective to analyse climate change adaptation strategies of rural people in dryland Cameroon

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Climate change has negative impacts on agro-sylvo-pastoral activities which represent the main livelihoods of the rural population in Dryland Cameroon. These impacts are experienced differently among distinct social groups (men, women, migrant and non-migrant, Christian, Muslim, etc...) present in the area. By applying an intersectional lens, this paper identifies the adaptation strategies of farmers and pastoralists in the Dryland Cameroon and analyses how the interaction between sociocultural norms/rules and identities shapes these adaptation strategies. The study is drawn on 61 in-depth interviews conducted with farmers and pastoralists in 5 villages in the North Region of Cameroon. The main results show that farmers and pastoralists of the North Region use both coping/short-term strategies (lower production cost, sale of livestock to solve an immediate problem, traditional astrology to get meteorological information, etc...) and long-term strategies (use of improved varieties, agroforestry techniques such as planting cashew nut and neem in the farm, as well as agroecological techniques such as the construction of dikes, stone barriers to prevent flooding and erosion, etc..).While long-term adaptation strategies are more used by men and non-migrants, women and migrants rely more on short-term adaptation strategies. Indeed, the access to the resources (land, credit, information, etc...) they need to put in place sustainable and off-farm measures (such as migration to seek employment), are highly constrained by socio-cultural norms/local rules related to their gender, marital status, religion and residential status that define their roles and responsibilities in their households and their communities. The paper recommends that climate change adaptation interventions, aimed at strengthening the adaptation capacity of the rural population in the North Region of Cameroon, should highlight the intra-gender and intra-residential status differences that shape adaptation options.

Keywords: Adaptive capacity, climate variability and change, dryland, gender, intersectional perspective

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Forecast-based humanitarian assistance before a weather disaster: Evidence from a randomised controlled trial

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With the ongoing warming of the global climate, weather extremes are occurring more frequently and with greater intensity. Smallholder farmers in the Global South suffer more than others due to their geographical exposure and their dependency on rain-fed agriculture. In the absence of effective climate change adaptation and disaster relief efforts, extreme weather events may destroy agricultural livelihoods and lead to cascading effects, such as forced migration and rising poverty. Forecast-based humanitarian assistance is a novel approach in humanitarian aid in the context of disasters relief. Practitioners utilise meteorological forecasts to act early and assist vulnerable households before a disaster strikes. Through enabling adaptive behaviour, early action is expected to reduce the impacts of disasters and the costs of relief actions. While humanitarian stakeholders place high hopes in forecast-based action, few rigorous scientific studies exist that evaluate its effectiveness. Our study seeks to address this knowledge gap by conducting an impact evaluation of forecast-based financing, using a Randomised Controlled Trial approach. Our focus is on Mongolia, a country that is increasingly afflicted by extreme winter events that threaten the livelihood of pastoralist households. We test whether unconditional forecast-based cash transfers delivered to pastoralist households in the midst of the extremely severe winter of 2020/21 have a causal effect on preventing socio-economic damages. Our study presents first results on the extent to which forecast-based cash transfers enable households to prevent a reduction in their herd size. Furthermore, effects on investments in shock coping strategies as well as broader measures of well-being, approximated by life satisfaction, are considered.

Keywords: Climate change adaptation, extreme weather events, forecast-based financing, humanitarian aid, impact evaluation, Mongolia, randomised controlled trial

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Effect of information sources on the adoption of adaptation strategies for climate change

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It is expected that the world's population will continue to grow in the coming years, putting additional demand and pressure on agricultural production. To meet the challenge of improving agricultural production despite the negative effects of climate change, farmers must adopt some adaptation strategies. This study aims to examine the effects of information sources on adopting climate change adaptation strategies. The study was conducted among 197 maize farmers in Oyo and Ibadan/Ibarapa Agricultural Development Zones in Oyo State, Nigeria. Findings revealed that the majority (94.4 %) of the farmers believe that climate change is an issue affecting their production, and 89.8 % of the farmers agree that adopting adaptation strategies for climate change will help increase their productivity and profitability. Probit regression model used to analyse the effect of information sources on the adoption of adaptation strategies revealed that extension agents have a significant positive impact on the adoption of intercropping, irrigation, cultivation of improved cultivars, and livestock rearing. Information sourced from agricultural development programmes has a significant effect on the adoption of irrigation and livestock rearing. Similarly, information sourced from the Ministry of Agriculture has a significant impact on the adoption of irrigation and livestock rearing, information from the Ministry of Environment positively affects the adoption of organic fertiliser and the cultivation of improved cultivars. Farmers' associations as information sources were significant in adopting intercropping, cultivation of improved cultivars, and agroforestry. Friends and family also positively affected the adoption of intercropping and agroforestry. The findings approved the importance of receiving information from various sources in adopting adaptation strategies to mitigate the effect of climate change. We recommend resources should be made available to extension agents, as they have the greatest influence on whether farmers will adopt adaptation strategies to help mitigate the negative effects of climate change. This would ensure that relevant information is delivered in an efficient and timely manner thereby increasing productivity and profitability.

Keywords: Farming households, information, probit regression model

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Assessing the relevance of drought duration on dryland rangelands: an experimental and modelling study

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Dryland rangelands contribute to the livelihoods of numerous people in southern Africa by providing ecosystem services such as forage for livestock. While the demand for ecosystem services (ESS) is growing, climate change effects such as droughts reduce ESS provision and cause degradation of drylands. Yet there are still knowledge gaps regarding the effects of drought duration and the interaction with grazing on dryland rangelands. We hence asked: (1) How resistant is herbaceous savannah vegetation to a two- and a six-year extreme drought under both grazed and rested conditions? (2) How do the different drought lengths influence the recovery after drought release?

To answer these questions, we used data from a field experiment in a semi-arid savannah region in Limpopo, South Africa. In this "DroughtAct" – experiment, treatments of drought (66%-reduction of ambient rainfall) were implemented for two and six years and contrasted by non-drought control treatments. All treatments were combined with both moderate grazing and resting. We annually collected data on ANPP (aboveground net primary production) and plant species composition over a period of seven growing seasons including one post-drought season. The experimental treatments were also simulated using vegetation modelling (aDGVM2), where we additionally simulated a ten-year recovery period.

Our results indicated minor impacts and a fast recovery after two drought years. The reduction of ANPP did not exceed the rainfall reduction. However, this changed from the third drought year leading to ANPP in drought treatments of only about 20 % as compared to non-drought control plots in the sixth drought year. While grazing initially improved drought resistance, it increased the harmful effects of a long-term drought. Species composition showed as well a strong response to the different treatment combinations. The

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model results matched during the first two drought years, while effects of a continuing drought were underestimated. Still, the model results supported faster recovery after a two-year drought.
Our results stress the relevance of drought duration for vegetation resistance and resilience. Rangeland management strategies must consider a declining forage provision, an increasing vulnerability of the vegetation, and longer recovery time after prolonged droughts.

Keywords: Climate change, drought experiment, resilience, resistance, South Africa, vegetation modelling

Impact of the caste system and altitude on smallholder farmers' climate change adaptation strategies in Nepal

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Nepal belongs to the top four most vulnerable countries to climate change. It is at high risk due to the country's fragile topography, climate-sensitive and subsistence livelihoods of the people, and low adaptive capacity. Glaciers and mountain snow are melting more rapidly in Nepal, which increases the risk of GLOF, landslides, and floods. The study explores the awareness of farmers and their perceptions of climate change, its impact on farming, and adaptation strategies undertaken by the different caste groups in the area for coping with climate change impacts. The study was conducted in three districts from each agroecological zone of Nepal. Mustang district, Baglung district, and Chitwan district are selected from Nepal's mountain, hill, and plain regions correspondingly. To better understand the study area and local traditional adaptative strategies to cope with climate change, focus group discussion and self-field observation were performed. The data were collected through a structured questionnaire survey of 400 smallholder farmers using the recall approach for the past ten to fifteen years. The finding suggests that the farmers have perceived the change in climate pattern of the study area and its negative impact on farming. Farm households have been trying to cope with the impacts by adapting to alternate farming options and practices using traditional and modern techniques. Out of many adaptation strategies, crop diversification, off-farm activities, agroforestry, and temporary migration are broadly used to cope with climate change in the study area. According to our findings, those who belong to the top of the hierarchical caste system are more likely to adapt than those at the bottom of the hierarchy. Likely, the impact was perceived to be higher in the community living at a higher elevation compared to those at lower elevation. Even though individual adaptation strategies are adopted in the area, the vulnerability of farm households to the impact of climate change still occurs in terms of the lack of knowledge and financial resources.

Keywords: Adaptive capacity, elevation, ethnicity, smallholder farmers

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Modelling the impact of climate change on crop production in Nepal

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Climate change is expected to impose pressures on crop yield and food security in Nepal. However, the real effect of the climate change on crop yield and food security is still unknown. In this context, we assessed the influence of three different climate change scenarios on the potential productivity of rice, maize and wheat in Nepal. The scenarios are based on SSP1–2.6 (low emissions due to strong mitigation), SSP3–7.0 (high emissions), and SSP5–8.5 (extreme emissions/unmitigated) and were run with three general circulation models GFDL-ESM4, IPSL-CM6A-LR and MPI-ESM1–2-HR, resulting in nine scenarios. The data were bias corrected as part of the Coupled Model Intercomparison Project phase 6 (CMIP6) and downloaded from he Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3b) database. We chose the periods 1989–2014, 2015–2045, 2045–2070, and 2071–2100 to represent the baseline, near future, midcentury and end of century climate, respectively. The data show that a delay of monsoon rainfall, a shifting of rainfall patterns, and increased air temperatures are to be expected in Nepal. With the different climate change scenarios as input, we used the bio-geophysical crop model EPIC to simulate crop yields under business-as-usual agriculture management practices, comprising of low fertiliser application rates and limited irrigation applications. The results show that the yields of all three crops will be affected by the changes in climate. They also show that the different ecoregions of Nepal, tropical terai, subtropical mid-hills and valleys, temperate mountains, and the Himalayas will be affected differently by climate change, indicating a need for region-specific agricultural adaptation measures.

Keywords: Climate change, crop modelling, crop yield, Nepal

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Attributing historical changes and recent events in crop production to observed climate change

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Agriculture is projected to be increasingly affected by climate change, not least in many tropical countries prone to food insecurity. Where and which observed variations in agricultural production are already attributable to climate change to date is less clear, although such climate impact attribution can be important for understanding and assessing loss and damage, for informing and financially enabling adaptation policies, and for motivating both adaptation and mitigation efforts. Here, we use observationally-derived counterfactual climate data together with both statistical modelling and process-based models for impact attribution in crop agriculture. For the latter, we use an ensemble of state-of-the-art crop models from the Global Gridded Crop Model Intercomparison (GGCMI) of the Agricultural Model Intercomparison and Improvement Project (AgMIP) and the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP3a). The use of a multi-impact model ensemble allows characterisation of model-contributed uncertainty and assessment of the robustness of the results. This study is complemented by work using statistical crop modelling approaches. The tatistical models complement the process-based models in terms of different shortcomings and benefits. For the factual and counter-factual climate we, use the recently published ATTRICI data set. The analysis includes both long-term changes globally and nationally as well as individual events in selected regions. By collaborating with international and local stakeholders, we maximise relevance of the results and ensure appropriate consideration of regionally relevant factors and data availability and quality issues. Our work combines perspectives of climate attribution, disaster risk reduction, and agricultural science to enhance the science of attributing climate impacts in agriculture relevant for loss and damage and beyond.

Keywords: Attribution, climate change, climate impacts, crop yields

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Climate change and macadamia tree production in Malawi

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Global climate change is altering the suitable areas of crop species worldwide, with cascading effects on people and animals reliant upon those crop species as food sources. Macadamia is one of these essential lucrative crop species that grows in Malawi. Here, we used an ensemble model approach to determine the current and future distribution of macadamia production areas across Malawi in relation to climate. For future distribution of suitable areas, we used the climate outputs of 17 general circulation models (GCMs) based on two climate change scenarios (RCP 4.5 and RCP 8.5). The precipitation of the driest month and isothermality were the climatic variables that strongly influenced macadamia's suitability in Malawi. We found that these climatic requirements were fulfiled across many areas in Malawi under the current and future conditions. Suitable areas for macadamia production are predicted to shrink by −18 % (17,015 km^2) and −21.6 % (20,414 km^2) based on RCP 4.5 and RCP 8.5, respectively, with much of the suitability shifting northwards. This means that some currently productive areas will become unproductive in the future, while current unproductive areas will become productive. Notably, suitable areas will increase in Malawi's central and northern highlands, while the southern region which is mostly lowlands will lose most of its suitable areas (100 % losses). Therefore our current and future projections provide critical evidence of the potential negative impacts of climate change on the suitability of macadamia production in the country. We recommend developing area-specific adaptation strategies to build resilience in the macadamia sector in Malawi under climate change.

Keywords: Climate change, ensemble model, macadamia, representative concentration pathways

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Climate-smart villages in Southeast Asia: the pivotal role of seed systems in rice-based landscapes

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Given the aggravating nature of climate change impacts, rice farming will more and more rely on improved resilience to climate variability and extremes. To this end, the climate-smart village (CSV) approach was developed to address specific challenges of smallholder farmers. Within Southeast Asia, the CSV approach has so far been applied in Myanmar, Lao PDR, Cambodia, as well as in Vietnam and the Philippines where national programs have taken it up and established multiple CSVs. In spite of distinct climatic conditions, all these CSVs have rice-based landscapes as a common denominator. This article focuses on the improvement of rice-seed systems as the core of introducing climate-smart agriculture (CSA) in these villages. The experience of a CSV in Lao PDR clearly shows community-based seed (CBS) systems as a viable CSV component. Moreover, the efficiency of CBS systems is enhanced when applied in combination with the following supporting climate-smart interventions: (1) training in improved crop and pest management through farmers' field schools, (2) awareness raising through photo exhibits and seed fairs, (3) participatory variety selection, and (4) climate risk mapping as a means for targeted distribution of improved rice varieties. The study also explored direct market access for CSV products by advertising both the generic aspects of climate-smart adaptation strategies and the location-specific stories of smallholder farmers. To this end, the emerging online retail economy could offer viable avenues for highlighting specific aspects of food production in CSVs to different groups of consumers (e.g., the "buy local" preference in the domestic market and climate change concerns in the international market).

Keywords: Adaptation, climate risk mapping, climate-smart agriculture, climate-smart villages, community-based seed system, crop management, Lao PDR, online retail, pest management, photovoice

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Performance of field crops in a semi-arid environment: climate change assessment

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Crops yield in semi-arid environments is highly impacted by climatic variables, especially in rainfed sector. In light of global warming, the annual temperature is projected to increase between 2 °C to 6 °C by the end of the 21st century. As consequence, food and nutrition security will be highly affected, particularly in marginal areas where the majority of the populace depend on rainfed agriculture for their livelihood and income generation. Therefore, the objective of this study was to investigate the impact of temperature-based and rainfall-based variables on the yield of four major crops viz., sesame, sorghum, millet and sunflower over 35 years in Gedaref state, Sudan. Firstly, the rainfall and temperature variability over the study period was assessed using the standardised anomaly index. Secondly, the Mann–Kendall trend analysis was employed to assess the existing positive or negative trends in temperature and rainfall over time. Thirdly, the relationships between climatic variables and crops yield was determined using correlation and multiple linear regression. The study shows that the annual minimum temperature (Tmin) increased by 0.05 °C per year, while maximum temperature (Tmax) increased by 0.03 °C per year. On the other hand, the annual rainfall fluctuated over time with no significant ($p \geq 0.05$) increase or decrease in the trend. A negative correlation was detected between the yields of all selected crops and Tmin and Tmax (correlation coefficient: r ranged between -0.09 and -0.76). However, the annual rainfall had a strong positive correlation with yield of sorghum ($r = 0.64$), sesame ($r = 0.58$), and sunflower ($r = 0.75$). Furthermore, amount of rainfall, Tmax and Tmin explained more than 50 % of the variability in the yield of millet ($R^2 = 0.54$), sunflower ($R^2 = 0.61$) and sorghum ($R^2 = 0.70$). The findings of this study could be used to raise awareness among different stakeholders especially, policymakers on the impact of climate change on food and nutrition security.

Keywords: Field crops, food security, global warming, rainfed agriculture, trend analysis

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Africa's woodlands in transition: effects of climate change, land-use change on plant functional diversity and their carbon pools

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Globally, forest and savannah ecosystems are among those containing the main carbon pools. Woody biomass within Africa's ecosystem stores about 25 % of tropical forest carbon. However, African forest and savannah ecosystems are currently experiencing rapid transitions due to deforestation and land-use intensification, with profound, usually negative consequences for carbon storage in woody biomass. At the same time, ongoing climate change is projected to have substantial effects on carbon pools, which potentially interact with the effect of land-use change. Moreover, climate and land-use change are known to be the most important drivers for biodiversity losses, which can in turn have indirect effects on carbon stocks. There is the need for a better understanding of how climate and land-use change jointly and directly affect carbon pools in Africa's woody vegetation. Likewise, we need to better understand the extent they exert indirect effects on carbon storage through their effects on plant diversity.

We will conduct a field study along a latitudinal climatic gradient in West Africa, from Sudan Savannah to tropical Guinean climate zone. Along this climatic gradient, four study sites will be located where we will capture local gradients of land-use intensity, spanning from protected areas over rangelands to intensively used agricultural fields. In this way, we can use a crossed space-for-time substitution for climate and land-use change, which will allow us to disentangle potentially interactive effects of these two global change drivers on carbon storage in woody vegetation. Aboveground and belowground biomass and carbon pools of woody vegetation will be quantified via novel methodology designed for disturbance-prone ecosystems. Woody species' plant functional traits in the global spectrum of plant form and function will be recorded to assess indirect effects of climate and land-use change on carbon stocks via their imprint on functional vegetation composition and diversity

Keywords: Biomass, carbon pools, climate change, functional diversity, functional traits, land-use change

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Dealing with climate data uncertainty for agricultural impact assessments in West Africa

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West Africa is characterised by high variability in climate, has a fast growing population, and is home to a population strongly reliant on rainfed agriculture. The largely weather-dependent agricultural production is now further at risk under increasing climate change. To adequately address climate risks and avoid further pressure on food security, evidence-based information on climate impacts and guidance on the suitability of adaptation measures is required. Simulations of regional impacts of climate change on crop production are strongly influenced by the climate data used as input. The selection of climate data is most influential in regions with high uncertainties in past climate data and where the agricultural production varies greatly under climate variability (Ruane et al., 2021). Both is the case in West Africa, calling for an improved understanding of past and future climate data for its use in agricultural modelling. In this session we want to contribute to an increased understanding on the usability of different past and future climate data sets for agricultural impact models over West Africa. We compared ten CMIP6 (Coupled Model Inter-comparison Project Phase 6) models and their respective bias-adjusted ISIMIP3b (Inter-Sectoral Impact Model Intercomparison Project Phase 3b) versions against different observational and reanalysis data sets. Focusing on their use for agricultural impact assessments we centred the analysis on climate indicators highly influencing agricultural production. Results show that the ten CMIP6 models contain regional and model dependent biases with similar systematic biases as have been observed in earlier CMIP versions. Although the bias-adjusted version of this data aligns overall well with observations, we could detect some regional strong deviations from observations in agroclimatic variables like length of dry spells and rainy season onset. The use of the multi-model ensemble mean has resulted in an improved agreement of CMIP6 and the bias-adjusted ISIMIP3b data with observations. The results of this study can support agricultural impact modelling in quantifying climate risk hotspots as well as suggesting suitable adaptation measures to increase the resilience of the agricultural sector in West Africa.

Keywords: Agricultural impact assessment, climate data, ISIMIP3b, West Africa

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Adptablility of climate smart agricultural practices in yellow cassava and implications in Nigeria

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The study evaluated the adaptability of climate smart agricultural measures of yellow cassava, linkages and implications in Nigeria. Multi-stage sampling procedure was deployed for sample selection which brought about 580 respondents. Data were collected using structured questionnaire and were analysed using descriptive statistics such as frequency counts, percentage, mean scores and beta regression technique. Results showed that yellow cassava farmers were more of males (60.2 %), married (80.0 %), and relatively educated (60.4 %). Major climate change hazards experienced by yellow cassava farmers include increased disease of crop (69.4 %), reduced soil fertility (76.7 %), and increased insect infestations (51.4 %). Assets deployed in yellow cassava production were tractors, mechanised harvesters, and family labour. Again, land tenure systems, family rules, funding agency guidelines, and extension agents were among the social institutions that influenced resource control of the cassava farmers. Alternative to agriculture (75.4 %), empowerment programmes (77.2 %), engagement strategies, and crop variety diversifications (97.0 %), were climate smart adaptive measures utilised in the area. Again, earthing up of cassava plot, change in spacing between plant stands, and change in farming systems were some of the new technologies and skills employed to enhance yellow cassava production. Majority of the farmers, (97.7 %) accessed climate information on radio and public places. Further, greater percentage of the farmers (89.0 %) had low adaptive capacity to climate change. Age, education, household size, and extension contacts influenced climate smart adaptive measures of yellow cassava. The study recommends farmers to cultivate more of yellow cassava because of its calorie content capacity and seek for early warning information on climate change to avert possible negative consequences.

Keywords: Beta regression, climate change, smart adaptive measures, yellow cassava

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Animals and livestock systems

Sustainable and resilient animal production systems

Rotational grazing and water conservation as a strategy to enhance pasture productivity and resilience in semi-arid eastern Kenya

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Livestock is an integral part of the livelihood of communities in semi-arid regions in Kenya, which occupy about 80 % of total land mass. Livestock serves as a safety net for food and economic stability, contributing about 12 % of Kenya's GDP and 50 % of employment in the agriculture sector. It is particularly important when dwindling rains do not support crop growth. In recent years, the impact of climate change has resulted in extended droughts, leading to overgrazing and land degradation due to trampling and soil erosion. Consequently, rejuvenation of pastures has greatly reduced leading to significant loss of livestock. Among the strategies to mitigate degradation and loss of pasture is exclusion of livestock from designated grazing areas and enhancing soil/water conservation. This paper presents a case study on the potential of paddocking as an alternative to traditional pasture use to increase productivity and resilience in lower Yatta in Kitui County. Three dominant grass species (*Cencrus ciliaris*, *Eragostris superba* and *Megathyrsus maximus*) were grazed for maximum three months, after which the animals were moved to another paddock. Shallow terraces were dug to conserve soil water and prevent soil erosion for three years. Observations were made on percentage of land cover after the rains, percentage of weeds in the pasture as well as the animal body condition throughout the year. Results showed that vegetation had rejuvenated to a land cover of 100 % at two months after onset of rains comprising of about 90 % pasture and 10 % weeds. The animals remained in good body condition throughout the year (BCS>5). These results demonstrate that pastures in semi-arid pastures can be resilient and productive if indigenous grasses are managed appropriately. The study recommends promotion of the strategy for sustainable livestock production in semi-arid regions.

Keywords: Paddocking, pastures, resilience, semi-arid

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Potential economic benefits of integrating silvopastoral arrangements in Latin American beef cattle fattening systems

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The environmental impacts caused by cattle are undeniable, and, in addition to the expansion of land, are related to biodiversity loss, deforestation, and greenhouse gas (GHG) emissions, making the sector a main contributor to climate change. Given the social and economic importance of cattle, it is crucial to implement strategies that can both mitigate environmental impacts and allow productivity increases. Silvopastoral systems (SPS) constitute a valuable strategy in this regard, since they generate environmental benefits, related to the reduction of GHG emissions, increased nitrogen fixation, and nutrient cycling, as well as economic benefits, such as increased production efficiency, reduced production costs, and the generation of additional income. This study evaluates the implementation of a SPS in beef cattle fattening (treatment 1, T1) in Colombia from an economic perspective and contrasts the results with a traditional grazing system under grass monoculture (treatment 2, T2). Information was collected in trials in Palmira, Colombia, during 2021 and 2022. The grass varieties used in both treatments were *Brachiaria brizantha* cv. Toledo and the *Brachiaria* hybrid cv. IATTC BR02/1752. The legume *Leucaena leucocephala* was integrated in the SPS (T1). We applied a discounted cash flow model for the estimation of profitability indicators, and a risk analysis. The results show a positive Net Present Value for both treatments. The probability that this indicator takes negative values is, however, with 21 % higher for T2 than for T1 (0 %). The internal rate of return is 21 % for T2 and 69 % for T1. The benefit-cost ratio indicates that for every US$ spent on the investment, US$ 1.5 are being obtained in T2 and US$ 2.7 in T1. The results suggest that the integration of *L. leucocephala* is economically and financially viable for the cattle producer and surpasses the traditional system. It leads to higher efficiency that allows increasing the annual income of the producer. The adoption of this SPS, in addition to its economic benefits, also contributes to conservation, resource-use efficiency, and mitigating GHG emissions. This study is a valuable input for decision-making in adoption processes of SPS in Latin America.

Keywords: Climate change, mitigation, silvopastoral system, sustainable intensification

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Water footprint of small-scale dairy farms in the central coast of Peru

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Dairy sector is said to consume 19 % of the water in the livestock sector. However, in Latin America the amount of water used in this sector is unknow, especially in arid zones. In Peru, dairy production is the second most important economic activity and one of the most important dairy basin is located in the arid zone of the Peruvian coast (47 % of the milk production). The aim of this work was to estimate the water footprint (WF) of dairy production in the arid zone of the Peruvian central coast. Data from five dairy farms were used to estimate the WF. The WF was calculated in its three dimensions: green water (rainwater stored in the soil and absorbed by the plants), blue water (consumptive use of surface or groundwater) and grey water (polluted water). In addition, the WF was measured for categories: feed, drinking and service. To measure the WF of feed production, the CROPWAT software was used. The reference unit was m^3 per kg of fat and protein corrected milk (FPCM). In average, 99 % of the WF comes from feed production, followed by drinking water (0.4 %). From the three dimensions of the WF, green water is responsible of 60 % of the WF, followed by the blue water (30 %). Imported water represented 63 % of the WF. In general, WF of dairy production in these systems was 0.66 m^3/kg FPCM. In conclusion, feed production, as the main source of WF from which most is imported, shows the possibility of reducing the WF of these systems by prioritising and optimising water consumption by crops using local resources with lower water requirements.

Keywords: Arid, cow, Latin America, milk, water footprint

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Socio-ecological context of Sumbawa buffalo depopulation: Evidence from eastern Indonesia

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Sumbawa buffalo in eastern Indonesia used to be called "Black Gold" by the island dwellers because of its great role and contribution in sustaining food security and socioeconomic livelihood. However, since past decade, this term has faded away. We conducted longitudinal studies in 2017 and 2021 aimed at identifying and explaining the trend, pattern, and determinants of Sumbawa buffalo declining population. The mixed-method was applied to investigate the effects of contextual factors and policy implementation beyond farmers' household and farming attributes in 143 villages of Sumbawa district, West Nusa Tenggara Province. The multiple OLS Regressions and Factorial ANCOVA were used to analyse the correlates of contextual factors attributable to the declining population based on Animal Unit measure as outcome variable. At village level, the findings suggest that carrying capacity, land degradation, and socio-potential factors have affected the buffalo depopulation [B=-0.672*, B=0.413, B=-0.361* respectively). Further multiple classification analysis denotes emerging interactions at two and three determining variables. On the other hand, the qualitative measures employing root cause analysis suggest that paradoxical cattle policy implementation in local governance and land degradation including deforestation were asserted to be the root causes and as core problems, operating through pathways of various social and agroecological undesired effects. Consequently, farmers who, faced with diminishing communal grassland area where to send buffalo for grazing, feel compelled to switch to another livestock farming. As policy and programmatic recommendation, unravelling the contextual determinants and enhanced policy formulation are absolutely needed to recover or avoid further declining productivity, otherwise Sumbawa buffalo, as some key informants said, might soon become endangered animal.

Keywords: Depopulation, grassland, livestock rural development, ruminant, socio-ecological, Sumbawa buffalo

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Effect of defoliation frequency in spring on the productivity and nutritive value of orchardgrass

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Efficient pasture-based animal production systems require optimisation of forage production with the highest nutritive value. Increasing the defoliation regimen of pastures allows to improve the nutritive value of forage for ruminants but it can be detrimental for total biomass production. An experiment was carried out to study the effect of the defoliation regimen around flowering time on productivity, chemical composition and nutritional value of tall fescue. The experiment was carried out on 4-year old orchardgrass (Dactylis glomerata cv 'INIA Perseo') pasture, at the experimental station "La Estanzuela" (INIA, Uruguay).

Three defoliation regimens: Severe (S), harvest at 2 leaf-stage, Lenient (L) at 4 leaf-stage, or Moderate (M) at 2 leaf-stage before flowering and at 4 leaf-stage afterward, were arranged in a completely randomised block design with 5 repetitions (blocks) in one paddock. There were three harvest events for treatment S and M and two for L treatment. Dry matter (DM), crude protein (CP), neutral detergent fibre (NDF) and *in vitro* digestible NDF (NDFD; Ankom Technology Corp., Macedon, NY) production (kg ha^{-1} d^{-1}) were determined for each treatment for the spring season (28/08/2019 to 25/11/2019).

The data were analysed using the MIXED procedure of SAS (version 9.1, SAS Institute Inc.) with treatment as a fixed and block as random effect. Means were compared with the Tukey–Kramer test. A higher DM production (76.5 kg ha^{-1} d^{-1})as a tendency ($p = 0.098$; SEM=1.81) was observed for the M than for the S and L treatments (69.5 and 73.2 kg ha^{-1} d^{-1}, respectively).

The S treatment showed the highest CP production (14.9 vs 12.6 kg ha^{-1} d^{-1} on average for the M and L treatments; $p = 0.038$; SEM=0.601) and a lower ($p = 0.033$; SEM=1.37) NDF production (39.0 kg ha^{-1} d^{-1}) than for the M treatment (45.9 kg ha^{-1} d^{-1}). There was no effect of defoliation regimen on the DNDF (26.7 kg ha^{-1} d^{-1}) average of the three treatments). The higher production of NDF and lower of CP for M than for S treatment could have been due because the harvest after flowering of this treatment was the latest in spring. The nutritional value measured from the digestibility of the NDF was not affected by the frequency of defoliation.

Keywords: Nutritive value, orchardgrass, ruminants

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Contribution of silvopastoral systems toward a sustainable livestock farming in the Amazonian foothills

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In recent years multifunctional arrangements integrating crop, livestock, and forest have been adopted in tropical areas. These arrangements known as silvopastoral systems (SPS) intend to improve animal welfare, to generate new economic, environmental, and climatic benefits. In Colombia, agricultural land has been predominantly used for the livestock sector. The Amazonian foothill, specifically the department of Caquetá had 6.9 % of cattle herds and was the fifth department for dairy production. Given this context, it is particularly important to implement SPS to protect the Amazonian forest and to avoid extensive cattle ranching in this zone. However, even though SPS are beginning to be promoted in Colombia as strategies for sustainable land management, the contribution of these strategies has not yet been fully explored. To address this challenge, this study used a modified version of contribution analysis to evaluate the economic, social, and environmental benefits, drivers and hinders factors, and negative externalities. Contribution analyses on SPS were developed with cattle farmers and other stakeholders in Caquetá using in-depth semi-structured interviews and two workshops (n=40). Contribution analysis proved to be a useful framework for assessing the impacts and valuable feedback for implementers and sponsors of this kind of strategy.
Results from the contribution analysis showed that the main benefits of SPS are: better feeding for cattle, higher dairy production, greater diversification on the farm, higher farm economic valuation, lower loss of the herd, greater welfare and life quality for producers, social awareness of the importance of buffer zones, efficiency in water use, greater availability of organic fertilisers and microorganisms, new training and knowledge, improved soil protection, landslide prevention, more shade, and less soil compaction. An important driver of these systems is the empowerment of both men and women to work together in the different tasks of this type of system. On the other hand, the lack of resources to replicate the strategy in larger areas of the farm and the lack of livestock water supply systems are frequently mentioned as hindering factors. Two negative externalities are important to take into account: shortages of electric fences and fuel needed to pump water to paddocks.

Keywords: Amazonian region, contribution analysis, silvopastoral systems, sustainable land management

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The changing land use and its impact on the traditional cattle production system in Sumbawa island eastern Indonesia: Current situation and the way forward

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Sumbawa island is one of a few islands in Indonesia that remains the major source of local cattle for inter-island export. Its cattle population has increased steadily from less than 100 in the 1970s to more than 600,000 in 2021. However, a rapid transformation is changing the cattle production system from large herd communal grazing system to semi-intensive smallholder system, that may decline the population of local cattle on this island in the near future. A rapid assessment has been conducted to analyse factors contributing to this transformation. The results show that the rapid transformation has been a result of massive change in land use in the last 20 years. The number of communal grazing areas in Sumbawa District for example, has declined from 59 sites 20 years ago to only 6 effectively functioning grazing area in 2021. Most of the grazing areas are now utilised for crop production (especially maize) in wet season. More than 1000 ha of a large communal grazing area in Dompu district has been converted to sugarcane production, forcing some of the animals to be taken home by the owners. Over grazing of the communal grazing areas also allowing a very extensive weed invasion. All these factors have caused significant reduction in carrying capacity of this grazing area in the last 10 years. On the whole island, a very rapid change in land use has been occurring in the last 10 years as maize production expanded extensively to cover dry land areas including communal grazing areas. Maize expansion not only occurring in the dryland areas, but also in the irrigated land. In the dry season, most irrigated land is now planted with maize, leaving a short period for cattle grazing from maize harvest to the start of the rice planting season. Considering smallholder system is not efficient for cow-calf production, many farmers have started to spare their own dry land areas only for cattle grazing. This seems to be a promising alternative, therefore supports should be provided for this private "mini ranch" system to make the cow-calf production system effective.

Keywords: Cattle production, communal grazing area, land use, weed invasions

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Emission intensity of livestock production in the periphery of Ouagadougou, Burkina Faso

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Up to one-third of livestock production in the Global South is now happening in and around emerging megacities because infrastructures to transport and process animal products are lacking in rural areas. Increasing urbanisation in the Global South leads to a growing demand for animal products and pressure on production means, e.g., agricultural lands. Combined, these two factors lead to intensification and specialisation of production. Intensification of production is considered the main pathway to reducing the emissions intensity of low-yielding livestock production systems often found in the Global South. However, the impact of the intensification strategy chosen by livestock producers on emission intensity is not well researched. Our study thus aims to understand and assess the relationship between emission intensity and chosen intensification strategies, taking urban and peri-urban livestock production in Ouagadougou, Burkina Faso, as case study. Feeding practices, weight gain, and milk production of cattle (n records = 617 of which 330 lactating cows) were monitored on 18 farms in 10 visits between October 2014 and January 2016 within the UrbanFoodPlus project (www.urbanfoodplus.org). Methane and nitrous oxide emissions due to enteric fermentation and manure were computed per kg of livestock product. Local Zebus were mostly kept for meat production and thus barely produced any milk (on average 1.7 liters d^{-1}; n = 153). Sahelian Zebus produced on average 8.2 liters d^{-1} (n = 55) and exotic crossbreds 9.0 liters d^{-1} (n = 122). On average, the diet of Sahelian Zebus had, however, a higher digestibility (64.2 %) than that of exotic crossbreeds (62.9 %). Sahelian Zebu thus potentially had a higher resource use efficiency and lower emission intensity per unit of milk. Our study contributes to the documentation of the global environmental impact of low-yielding yet intensifying livestock production systems in the Global South. It also highlights the complex links between livestock production systems, urbanisation in the Global South and emission intensity of animal products.

Keywords: Cattle, dairy, Global South, intensification, urbanisation

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Agronomic evaluation of 25 accesion of *Clitoria ternatea* in time of maximum and minimum rainfall in Colombia CIAT HQ

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It is currently estimated that the area used for grazing cattle feed in the world is around 3,200 million hectares, this includes fattening, dairy and dual-purpose cattle. Most of this area is in extensive grazing systems under native pastures that, although of good nutritional quality, have a limited supply of forage, especially in few critical areas. This has caused cattle ranching to become a seasonal activity in the tropics, since in periods of low rainfall, ranchers struggle so that their animals do not lose weight and, in the worst case, because they do not die. Therefore, this leads to an inefficient use of the area used for livestock, obtaining a very low stocking rate per hectare. In Colombia there are around 33.8 million hectares under grazing with a livestock inventory of around 29.3 million head of cattle and a stocking rate of 0.86 animals ha^{-1}; being necessary to introduce new forage materials adapted to the conditions of the American tropics in order to increase the forage supply available for animals in critical times and that, in turn, it is of excellent nutritional quality. In this work, the agronomic and productive parameters of a collection of 25 accessions of *Clitoria ternatea* that included a control, *Clitoria ternatea* CIAT 20692, are analysed. The materials were evaluated at the headquarters of CIAT Colombia and the evaluation phase comprised the periods of October 2020 to December 2021 in two seasons, maximum and minimum precipitation and three regrowth ages per season (35, 42 and 49 days post-cut). It was found that the best age to harvest was 49 days and the best accession in terms of forage production was CIAT 17768 with a production of 7.61 ton DM/ha/cut, followed by CIAT9336 with 6.74 and CIAT712 with 6.73 respectively. For its part, the control, CIAT 20692 produced 5.36 ton DM/ha/cut.

Keywords: Extensive grazing, forage production, nutritional quality

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A G-FEAST approach to assess forage production in dairy production systems in western and central regions in Uganda

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Livestock is an important part of smallholder livelihoods in mixed crop/ livestock systems in East Africa and provides incomes and other livelihood opportunities. In Uganda, the dairy sub-sector contributes to more than 9 % to the national GDP. Livestock production is characterised by sub-optimal feeding. Hence the need to improve the availability of high-quality feed all year-round. However, improving forage production is constrained by the production and distribution of quality forage seeds including vegetative splits. This study was conducted to assess feed and forage production and use, the roles of improved forages in livestock diets and potential for forage seed production in Uganda. This study was conducted in five districts covering improved intensive system, improved extensive system and traditional extensive system of Uganda. The Gendered Feed Assessment Tool (G-FEAST) was used to assess the livestock production systems. Findings showed that farmers in improved intensive systems had small land sizes of 0.75–3 ha, and practised cut and carry feeding system. Purchased feed, grazing, collected feed and cultivated fodder contributes 79 % 10 %, 10 % and 1 % respectively to the total dry matter intake. The improved extensive systems have large farm sizes of 1–65 ha with grazing on improved and fenced pastures is common. Grazing contributes 80 % while cultivated fodder contributes 18 % of total on-farm diets. Crop residues constitute about 1 %. There are strong dairy cooperatives supporting milk marketing. The traditional extensive system has large farm sizes of 1–65 ha. Grazing on unimproved pastures, cultivated fodder, collected feeds, crop residues, and purchased feed contributes 67 % 16 %, 13 %, 3 %, and 1 % respectively of the dry dietary matter. On gender issues, both men and women are actively involved in decision making on livestock and forages. Women are more involved in animal husbandry practices ensuring animals are fed and cows milked. Women are also involved in forage production and feeding at farm level underpinning the importance of involving both men and women in promoting improved forages.

Keywords: Forages, G-FEAST, livestock, seed system, Uganda

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Agronomic evaluation of 15 *Centrosema* sp. under three regrowth ages at CIAT HQ, Colombia

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Much of the tropical livestock sector is managed in extensive grazing systems and in most cases with native and/or naturalized germplasm. Management practices in livestock farms do not only include the rotation of paddocks, adequate periods of occupation and rest, and the pasture areas are competing with other uses for land (e.g., deforestation, crops).
That is why it is necessary to introduce new forage germplasm, which adapts to adverse conditions, provides excellent nutritional quality, and allows intensifying livestock systems, freeing areas used for grazing to be used as a reforestation area or for planting crops, among others. The objective of this study was evaluating the agronomic and productive behaviour of a collection of 15 accessions of *Centrosema* spp. in two climatically contrasting seasons and with three regrowth ages (Cut 1:35, cut 2: 42 and cut 3: 49 days post-cut). According to the information obtained in the study in terms of biomass production of each accession averaging the two climatic seasons, it was found that the accession that presented the best performance in terms of biomass based on dry matter (DM) was CIAT 15474 in the Cut 2. with a forage offer of 7.12 ton DM/ha/cut, surpassing the control (CIAT 15160) that produced 6.55 ton DM/ha/cut. These data indicate that the accession that emerged is a promising option for adoption in livestock systems in Latin America. However, it is recommended to compare the information obtained with the results of other related research in order to identify production niches for it. Likewise it is recommended to conduct studies on seed production and dissemination with producers to facilitate adoption processes.

Keywords: Cattle, forages, germplasm, sustainable intensification

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Silvopasture in the Amazon is more productive and profitable than grass only monocultures

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Unsustainable cattle ranching in the Amazon leads to land degradation and incentivizes deforestation. Planting trees in pastures ('silvopasture' or 'silvopastoral systems') is a novel approach that has the potential to increase the sustainability of cattle production in the Amazon. Trees provide additional feed whilst also enhancing biodiversity, capturing carbon and improving soil quality. We measured the potential contribution of tree forage to pasture-fed cattle at a trial farm in Peru. Three leguminous tree species (*Erythrina berteroana*, *Inga edulis* and *Leucaena leucocephala*) were planted with grass, and their productivity was compared to plots containing only grass. We compared destructive and non-destructive methodologies that estimated intake of tree forage by browsing cattle. We found that fresh tree foliage of the three tree species was palatable to cattle and could be directly browsed. Cattle mostly foraged below 1.6 m and consumed 99 % of available foliage from *E. berteroana*, 75 % of available forage from *I. edulis* and 80 % of available forage from *L. leucocephala*. Plots containing trees and grass produced more forage biomass (mean > 2.2 Mg ha^{-1}) than grass only plots (mean = 1.5 Mg ha^{-1}). This research highlights the potential for sustainable intensification of livestock production in the Amazon. The talk will also highlight the key findings of extension and practical work in silvopastoral systems carried out in Peru, Bolivia, Brazil and Guyana over the past decade, consider the challenges to implementing silvopasture at scale and what steps can be taken to promote the adoption of silvopasture among farmers across the Amazon.

Keywords: Adaptation, agriculture, agroforestry, Amazon, cattle, climate, livestock, mechanisms, methodologies, mitigation, Peru, silvopastoral, silvopasture

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Agro-ecological analysis of Zambia's dairy subsector

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In Zambia, the livestock sector contributes 3.2 % to the overall national gross domestic product, and 42 % to the agricultural GDP. Livestock products such as dairy are essential for Zambia to eliminate all forms of malnutrition by 2030 as stated in the National Food and Nutrition Strategic Plan (NFNSP). The dairy value chain not only improves the food security of milk-producing households in Zambia but also helps to create numerous employment opportunities throughout the value chain. Dairy foods are a standalone food group because of their sole calcium contribution to the diet, having a hydrating power more than that of water, they are effective as carriers of probiotics and have been credited with protecting various aspects of oral health, gut health, and overall immune function. However, the consumption of dairy products in Zambia is low despite increased household income in the last two decades. For example, per capita annual consumption of milk in Zambia stands at 16.5–19.4 liters against the 200 liters recommended by the World Health Organisation (WHO). To address the challenge of low dairy per capita consumption, a holistic and integrated agro-ecological approach must be applied to understand the economic, environmental and social factors constraining the sub-sector to fully realise its potential to feed the country and the world at large. Agro-ecology is a food production system that not only produces food, jobs and economic well-being but also creates cultural, social and environmental benefits. The agro-ecological system hinges on three operational principles of improving resource efficiency, strengthening resilience and securing social equity or social responsibility. Development of a self-sufficient dairy industry in Zambia, economically still awaits the enactment of the livestock development policy as the necessary regulatory framework for an enabling environment for improving access to production inputs, establishment of more raw milk bulking centres country-wide and subsequent stimulation of local processing of dairy products. Socially the level of women participating in the value chain is significantly low at only 25 % with men at 73 % and the youth at 1.4 % attributed to patriarchal cultural practices in land and cattle ownership overlooking the time, energy, creativity and knowledge contribution from women to production, processing and marketing of dairy products. Furthermore, there is limited dairy consumption among adults as the products are especially consumed by only children in most households due to high product prices and poor perception. And on the environmental angle, there is unsustainable open community grazing practices which has resulted in loss of biodiversity, also absence of a Greenhouse gas (GHGs) emissions protocol for dairy production regardless of the large carbon print that dairy production has. Dairy production also has significant water resource requirements for sustained milk production. Application of agro-ecological principles is critical for the future sustainability of the sub-sector.

Keywords: Agro-ecology, dairy, livestock, Zambia

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Refinement and scaling of inclusive agroecological innovations for livestock management, crop rotations, and soil conservation in semiarid south Mediterranean regions

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Mixed crop-livestock farming systems are generally productive systems that face major efficiency and resilience challenges, especially in arid and semi-arid areas where biomass availability is quite low. The integrated management of natural resources, especially soil fertility, through enhanced agroecological practices, is more complex under these systems due to acute trade-offs between the use of available biomass for the immediate satisfaction of livestock needs (grazing), vs. their use to improve soil fertility (organic matter cycle/residue recovery). It is therefore important to consider a systems approach when working on better integration of these key components of the agricultural system, namely, crop, livestock, and soil. These components are themselves linked to other socio-economic, social, and environmental contextual factors, which adds complexity to development actions aimed at promoting agroecological practices in this type of system. A set of integrated interventions (innovations/packages) is essential to improve the performance and integration levels. The objective of this paper is to i) present a socio-technical package of agroecological interventions that are already being tested for this type of mixed farming system in the semi-arid area of Tunisia, and ii) illustrate the scope and mechanisms for scaling up this package. The study was based on the piloting of a co-designed innovation package including conservation agriculture techniques, enhanced plowing and seeding methods, livestock grazing, and health management, in addition to rural women empowerment, among others. Strategic partnerships for scaling were also effectively designed across public and private actors, and widely contributed to the success of the scaling approach. Results further illustrate the key factors that have led to a change in attitude and behaviour among local actors and farmers towards a better co-generation, co-sharing, and adoption of agroecological principles at farm, community, and landscape levels.

Keywords: Cereal, crop-livestock, innovation packages, mixed systems

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The role of cell phone-based apps on cattle farming in Africa: a review

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Inefficiency and improving the productivity of animals are the primary challenges of the livestock sectors in Africa. Utilizing ICT (Information Communication Technology) tools is one way to improve efficiency. Through ICT use, cattle nutrition, performance and health can be enhanced and monitored. Despite its significant contribution, ICT for livestock production in Africa is at its early stage of growth.
In Africa, there are approximately 60 mobile-based applications designed for livestock farming. In order of distribution, Kenya is ranked first, followed by Tanzania, Uganda, and Nigeria.
There are six main categories of such applications available in Africa: information generation, livestock farming, financial insurance, market access, supply chain management, and micro-farming intelligence. For example, Esoko for marketing information (used in 15 countries in West & East Africa), Afriscout for pasture and waterholes finding app for pastoralist (Kenya), myAnga for forage and weather forage condition forecasting app (Kenya), Farmable for raising funds to purchase dairy cattle breeds (Ghana), iCOw for market information sharing app (Kenya, Ethiopia, Tanzania), and Cowtribe for animal health tracking app (Ghana).
The Market Oriented Dairy Ration Formulation Tool (MOD-RAFT) developed by the University of Florida, USA, and used in Uganda, and Fodjan, developed by the University of Hohenheim, Germany, is used in Kenya. It is pertinent in this context that the formulation of rations and the levels of energy fed to cows daily (energy fed per cow per day) are crucial for milk production in dairy herds, as feed represents the central portion of costs in milk production (80 %).
Mobile penetration and growth in Africa are the highest, which makes mobile-based ICT tools used in agriculture more feasible. Despite their increasing popularity in supporting farm decision-making, few studies have been performed on their adoption, acceptance and determinant factors.
Hence, this poster aims to briefly present the status of cellphone-based ICT tool use in the livestock sector, provide baseline information for further research, and support the digitisation efforts of the livestock sector in Africa by pointing out research gaps.
Keywords:

Keywords: Africa, applications, cattle, cell phone, decision, farming, livestock, tools

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Rangeland desertification and land use changes on commercial land in Nambia's Waterberg region

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Looming desertification and ongoing climate change put semi-arid rangelands and thus fodder resources for livestock and farmers' livelihoods under increasing pressure. In Namibia, the driest country in sub-Saharan Africa, cattle farmers are repeatedly forced to apply short-term risk coping and long-term risk mitigation strategies to maintain their farming business. This distinct interdependence between society and nature make Namibian rangelands a prime example for tightly coupled social-ecological systems (SES). In order to sustain rangelands in the face of rapid global environmental change, a deeper understanding of land use and land cover changes and their drivers and related effects is necessary.

Addressing the complexity of rangelands as SES, a mixed method approach was chosen comprising remote sensing techniques, semi-structured interviews with freehold farmers, participatory on-farm mapping, and archival research of the historical development. An object-based classification of aerial photographs and satellite images was applied to classify land cover and investigate the changes from 1961 onwards.

The most important changes over the past 60 years include the progressive bush encroachment, its containment by de-bushing, the subdivision of rangeland into progressively smaller management units, and income diversification. Overall, the area of shrub-dominated savannah has increased by 18 % and the area of grass-dominated savannah has simultaneously decreased by the same amount within the last 60 years. However, the extent of this varies greatly among farms in dependence of the underlying site conditions and applied management strategies.

Direct causes of land cover changes are driven and shaped by underlying, synergistically acting socio-economic (e.g., market/price changes, guidelines, policies) and biophysical drivers (e.g., resource scarcity, site conditions, rainfall variability). In particular, climatic trigger events (e.g., droughts) associated with short-term and long-term land use changes play a key role.

To achieve sustainable future land use, small-scale selective bush control and aftercare measures, the full utilisation of removed shrubs, further diversification of farm-income generating activities, strategic decision-making, and proactive management are pivotal.

Keywords: Cattle farming, freehold farmers, land cover changes, object-based image classification, savannah, social-ecological system

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Functional diversity as an indicator of rangeland degradation – insights from a Namibian grazing gradient study

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Degradation of semi-arid rangelands is associated with a sharp decline in the delivery of critical ecosystem services such as forage production. Droughts and overgrazing – or a combination of both –– may lead to reduced herbaceous production, the loss of palatable grass species, and bush encroachment. During the process of degradation, several ecosystem components change, such as plant community composition. Therefore, taxonomic and functional diversity might be valuable indicators of ecosystem state, as losses of species or functional strategies might strongly affects ecosystem functioning and ecosystem services. However, while the response of taxonomic diversity to rangeland degradation has been frequently evaluated, there is still limited knowledge. We therefore included the following questions in our study: (1) Are there patterns of shrinkage of functional trait spaces as grazing pressure increases? (2) How does the management regime influence the stability of taxonomic and functional diversity? (3) Can functional diversity serve as indicator of degradation?

To answer these questions, we conducted a space-for-time substitution for land-use intensification in semi-arid Namibia. We studied 16 grazing gradients (transects) starting at a livestock watering point where grazing pressure was assumed to be highest. Transects were distributed over four commercial and four communal farm areas, with commercial farms characterised by rotational grazing, and communal farms by permanent grazing. Plant community composition of the grass layer was recorded on nine (10×10 m) plots per transect (162 in total). For 142 dominant species contributing > 90 % of the biomass, we measured a set of plant functional traits related to plants' life-history and resource acquisition strategies, and calculated indices of taxonomic and functional diversity, and functional trait spaces.

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Results indicate no clear trends along grazing gradients, but differences in taxonomic diversity and functional trait spaces between management systems. Rangelands characterised by continuous grazing, heavy bush encroachment, and low densities of palatable grass species had narrower functional trait spaces. This may indicate the loss of functional strategies in the process of rangeland degradation. We conclude that measuring functional diversity can improve understanding of degradation processes and helps in developing strategies to prevent them.

Keywords: Arid ecosystems, ecosystem services, ecosystem stability, land degradation, plant functional traits, rangeland management

Relationship between heat stress perception and adaptation strategies of poultry farmers in Bauchi state, Nigeria

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Nigeria's poultry industry is expanding, especially since the government prohibited the importation of live or dead birds and frozen poultry and bird's eggs. This contributes to the growth of the industry. However, on the other hand, heat stress has been shown to have a negative impact on poultry production in Nigeria and other tropical countries. The study examined the relationship between heat stress perception and adaptation strategies of poultry farmers in Bauchi State, Nigeria. A multi-stage sampling technique was used to select 240 registered poultry farmers for the study. The poultry farmers' information was gathered using a structured questionnaire. Result of the study revealed that majority (75.0 %) of the poultry farmers perceived a poor eggshell quality, reduction in egg size (79.2 %), difficulty in breathing (72.5 %), high mortality rate (75.8 %) and 64.2 % reported low response to treatment in their flocks. To mitigate the effects of heat stress on their birds, poultry farmers in the study area adopted the following adaptation strategies.; less heat supply (87.2 %), planting trees around the pen (88.3 %), creating more space per bird (96.7 %), change in feed formulation (60.0 %) and well-ventilated houses (94.2 %). The correlation result revealed a positive relation between slow growth rate and change in feed formulation (r^2=0.234**), increase in water intake and less heat supply (r^2=0.999**) and poor eggshell and provision of well-ventilated house (r^2=0.195**). Based on the findings of this study, we recommend that poultry farmers acquire more training on heat stress adaptation strategies on poultry sector resilience and to adapt with changing climate.

Keywords: Adaptation, climate change, heat stress, Nigeria, poultry

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Integrating crop pollination management, native beekeeping, and silvopastoral systems to improve the cattle sector's sustainability in Latin America

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Insect pollinator biodiversity and occurrence is on global decline, threatening human food supply and ecosystem functions. Extensive, pasture monoculture cattle production systems in tropical Latin America are among the principal drivers of this decline. This, in combination with other environmental problems caused by the conventional cattle sector, such as deforestation or greenhouse gas emissions, puts emphasis on the development of alternative, more sustainable production systems. One solution is the inclusion of forage legumes (fabaceae) in cattle production systems, for example as forage banks or within silvo-pastoral systems (SPS), which are mostly pollinated by insects, in particular bees. Such systems have been widely promoted to improve livestock production and soil fertility, but not to enhance ecosystem services from pollinators. Shortages of seed for the establishment of legumes as forage banks or within pastures or SPS remain a bottleneck for the improvement of ecosystem services brought about by pollinators within these systems and beyond. Against this background and based on literature review, we provide an overview of forage legumes, their interplay with pollinators, and the ecological and socio-economic benefits of pollinator–forage legume interactions, at different scales (farm and landscape level). We also discuss the challenges and opportunities of scaling these sustainably intensified cattle production systems that integrate legume forage-seed production with principles of pollinator ecology and native beekeeping. Our analysis shows that the main benefits include the provision of habitats for pollinators on decline and the promotion of legume seed required for the wider adoption of sustainable, forage-based cattle systems. This comes along with livelihood benefits for the producers, who can diversify (cattle production, legume seed production, honey making) and increase their incomes. At the landscape level, the interplay of pollinators and forage legumes can positively affect the yield of nearby pollinator-dependent crops. Finally, we provide interested stakeholders, policy- and decision-makers with a perspective on how such agroecosystems may be designed and scaled into multifunctional landscapes. This includes the improvement of enabling conditions, such as policies, knowledge transfer, payment schemes for ecosystem services, incentives, and new value chains.

Keywords: Cattle, ecosystem services, forage legumes, meliponiculture, nature-based solutions, pollinators, silvo-pastoral systems, sustainable intensification

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A shift in aim of rearing cattle by the farming communities: a case study in some districts of Gangetic West Bengal (India)

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Market driven economies at many times overrule the subsistence farming in several parts of the developing countries and those in India are no exception. Livestock rearing has been an integrated part of the Indian agricultural system. Cattle were raised primarily as a source of draft and milk. Bullocks were an integral part of almost every agrarian household and agricultural practices were correlated with their presence Milk and dairy products are integral part of the culinary and the culture of the country. In the past the women of the household were responsible for rearing the livestock. The native cattle were raised for high fat milk while the bullocks were more a source of farm power. In the gangetic parts of West Bengal (India) the overall cultivable land holding has decreased over the days due to several anthropogenic reasons. Large tracts of cultivable land are battered with severe cyclonic storms several times a year. The bullocks are being replaced by farm machineries especially power tillers. Thus, fattening cattle has become a new source of income. The bull calves are sold in livestock markets in Southern parts of the state. These calves are purchased from the farmers by the middlemen. The calves are stall fed for several months and are generally raised on paddy straw and some grass. They are seldom provided with any concentrates which is attributed to the lack of resources by the rearers. Some farmers have also reported the uses of anabolic steroids for fattening the steers which can have serious implications on the steers and the consumers alike. These cattle are at times under contract farming by the landless farmers. The fattened steer are generally sold off during the Eid ul Adha festival. This recent shift in cattle rearing practices is becoming popular over time and practiced generally by landless farmers. The calves are generally of Gir and Sahiwal crosses which adapt well when compared to the taurine crossbreds. As such practices are generally of recent origin the farmers reported that traditional fattening methods could be improved through proper training and extension program.

Keywords: Economics, extension, fattening, livestock, milk

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Improvement of fodder autonomy of livestock in the north-sudanian zone of Burkina Faso

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One of the major challenges of the livestock sector in Burkina Faso is to meet the feed needs of livestock to improve their productivity. This situation becomes even more critical when it is correlated with frequent security crises in certain areas, limiting transhumance and leading herders to settle down. This study aimed to contribute to the improvement of fodder availability in quantity and quality in the commune of Korsimoro (centre-north Region), with a view to ensuring feed autonomy for livestock. It consisted first at making an inventory of the feed resources available for livestock from 135 farmers by means of a formal survey; and second to test on farm dual purpose varieties of sorghum (Sariasso 14) and cowpea (KVX 745–11P), the main crop in the area, with 30 target farmers.

The inventory revealed 04 main types of feed (grass from natural pastures, woody fodder, crop residues and concentrates feed), whose availability varies over time, resulting in a feed shortage at certain periods of the year. This lack of feed resources is accentuated by inappropriate storage and conservation methods (sheds, tree branches, roofs of houses), which decrease their nutritional value.

The two dual-purpose crop varieties tested proved to be very satisfactory, as they combined high yields of fodder especially and a good determination of farmers to adopt these crops (68.18 % for sorghum and 83.33 % for cowpea). The average grain yields obtained varied from 1.5 ($\pm$0.8) t ha^{-1} for sorghum to 0.6 ($\pm$0.3) t ha^{-1} for cowpea. The corresponding fodder yields were 5.1 ($\pm$2.3) t ha^{-1} for sorghum straws and 2.7 ($\pm$2.8) t ha^{-1} for cowpea haulms. The adoption of fodder crops of dual purpose constitutes a resilient solution to the feeding needs of the livestock and the populations, and therefore the best strategy for the development of livestock farming in Burkina Faso.

Keywords: Cowpea "KVX 745–11P", dual purpose fodder crop, feed resources, fodder conservation, sorghum "Sariasso 14"

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Typology and characteristics of peri-urban dairy cattle farms in the coastal areas of Benin

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In sub-Saharan Africa, rapid population growth, urbanisation, and increasing incomes are the main drivers of the rising demand for livestock products, especially fresh milk and its derivatives. To meet this demand, there is an increasing number of dairy cattle farms in the densely populated coastal zone of Benin, where the country's largest city and commercial capital Cotonou is located. This study aimed to identify and characterise the peri-urban dairy production systems, and to understand how they operate and adapt to the ongoing urbanisation with its challenges. A total of 190 cattle farms were randomly selected and surveyed in four municipalities neighbouring Cotonou. Information on their socio-economic characteristics, cattle herd sizes, and herd management practices were collected through questionnaire-based face-to-face interviews. Factor analysis of mixed data followed by hierarchical clustering on principal components, implemented in R Statistical Software, were applied to classify the surveyed farms into homogeneous groups. Results revealed six types of peri-urban dairy cattle farms differing mainly in their cows' breeds, herd sizes, and daily amount of milk produced. Most (88 %) of the herds were owned by urban dwellers, mainly functionaries and traders, who entrusted cattle management to hired professional herders. Irrespective of farm type, cows were of local taurine (63 %) or Sahelian Zebu (37 %) breeds and were exclusively fed on communal natural pasture. Mineral supplementation was provided to the animals in 42 % of farms, with significant variations across farm types. About 45 % of the farms integrated cattle production with other agricultural activities, including coconut plantations (22 %), where cow manure was used as fertiliser. With significant ($p \leq 0.028$) variations across farm types, produced milk was either transformed into traditional cheese (32 % of farms) or sold raw. Milk and cheese sales represented 84 % of the total farm income for 3 out of the 6 farm types ($p \leq 0.019$). In the current context of rapid urbanisation, communal grazing lands alone cannot provide pasture to support increase in milk production. Farms that mainly use local taurine breeds could be targeted for agroecological transitions, as these breeds are more adapted to local environmental conditions and require relatively lower feed, labour, and healthcare than Sahelian zebus.

Keywords: Cow milk production, herd size, smallholder livestock keepers, typology, urbanisation, West Africa

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Agro-pastoralist farmers' perceptions of dairy cattle breeds and breeding strategies in northern Benin

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To understand farmers' preferences and perceptions of dairy cattle breed attributes and breeding practices, including selection criteria, 150 agro-pastoralists in northeast Benin were interviewed in a cross-sectional survey. Respondents scored their preference for cattle breeds, traits, and selection criteria of breeding stock on a scale of 1 (most preferred) to 5 (least preferred). Rank means (RM) and relative importance (RI) of preferred traits associated with cattle breeds were calculated and compared between farm types (sedentary or transhumant). Results showed that the Gudali breed (RM: 1.09) was most preferred, followed by Yakana (RM: 2.14), while the indigenous Borgou (RM: 3.34) was least desired. Zebu Gudali breed was preferred by transhumant ($p < 0.01$), while sedentary farmers preferred Zebu Yakana. The relative importance given by respondents to the different trait preferences revealed that the Gudali breed was preferred for its high milk production (RI: 4.93) and big body size (RI: 4.35). Zebu M'bororo was preferred only for its high milk production (RI: 3.01). The Yakana breed was chosen for its big body size (RI: 3.73), its adaptability to harsh environments (RI: 4.62), and its low feed requirement (RI: 4.01). However, the indigenous Borgou was the only breed preferred for its high fertility (RI: 2.51). Breeding practices were similar in replacement strategies, uncontrolled mating, and no record keeping. The common criteria mentioned by farmers for the selection of breeding females were the milk yield (RI: 3.03), the calves' survival in the first 03 months (RI: 2.05), and the earlier sexual maturity (RI: 1.94). All farmers had a least one bull, that age at first service was 4.07-year-old. Transhumant herds used Yakana bull, while sedentary farmers preferred either Yakana or Gudali bull. The replacement of the indigenous Borgou breed in its original belt by more milk-producing breeds calls for this breed conservation. Community-based breeding programmes for pure Borgou cattle and crossbreds aiming to improve body size and milk production could be implemented.

Keywords: Borgou, Gudali, small-scale, trait preference, West Africa

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Feeding and spatial behaviour of free-grazing cattle in the upper Ouémé basin of Benin

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Cattle are mainly fed on natural pastures in West Africa. The scarcity and degradation of rangelands strongly contribute to changing the behaviour of animals on natural pastures. Feeding and spatial behaviour of livestock on pasture determines the dry matter intake and the nature of forage resources selected. This study aimed to analyse the feeding and spatial behaviour of cattle over the pastoral calendar in the districts of Tchaourou and Djougou in the Upper Ouémé Region in Benin. Feeding and spatial behaviour of cattle were studied in six categories of cattle herds, including small herds (20–50 head), medium herds (50–100 head) and large herds (>100 head) monitored daily at grazing, each for five days according to the five grazing periods (Yannè, Dabune, Ceedu, Seeto, Ndungu) on the communal pastures of Tchaourou and Djougou. Global Positioning System (GPS) was used to record the livestock movements on pasture. The recorded animal positions and direct field observations were used to record the different activities of the animals and the feed intake during grazing. Results revealed that pastoral seasons strongly influence the travel times of grazing cattle ($p < 0.05$). However, they had no significant effect on the distances travelled in the two districts ($p > 0.05$). On the other hand, cattle herd types have a statistically significant effect on distances travelled by animals ($p < 0.05$). Cattle grazing activities also have a significant influence on travel times ($p < 0.05$). In addition, cattle herd types have a significant effect on dry matter intake ($p < 0.05$). The main resources ingested by cattle on rangelands are herbaceous, especially Poaceae (63.6 %), woody species, mainly Fabaceae (45.4 %) and domesticated resources, especially Poaceae (30 %) and Fabaceae (40 %). These findings are useful for sustainable management of rangelands and better monitoring of grazing cattle herds.

Keywords: Benin, grazing time, livestock monitoring, rangeland, travel distance

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Assessment of diurnal fluctuation of water quality parameters in different types of ponds In Rupandehi district, Nepal

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The number of farmers involved in fish farming is gradually increasing in Nepal, especially in the Terai region where fish are cultured in earthen ponds, concrete ponds and plastic ponds in intensive or semi-intensive way. Assessment of diurnal fluctuation of water quality parameters was carried out in 18 selected ponds from Siyari Municipality of Rupandehi district, Nepal in the year 2021. The treatment consisted of pond type as between-subject factor with six earthen nursery ponds, Six earthen production ponds and six plastic production ponds. Data were taken by using Aquaread, a multi-parameter water quality testing meter, at dawn (6 AM), noon (12 PM), dusk (6 PM) and night (2 AM), with Time as within-subject factor. Ten repeated observations were taken on cloudy and sunny days during three summer months viz. March, April and May. Field determination of physical (temperature and total dissolved solid) and chemical (pH, dissolved oxygen, salinity, electrical conductivity and oxygen reduction potential) properties of water was carried out. Statistic values of mean and range were computed and represented graphically using MS-Excel. Variation in each parameter at different sampling hours in three types of ponds were compared by Repeated Measures Analysis of Variance (ANOVA) using R-studio which showed that the values varied with time and day of observation, but not with pond type. Pairwise comparison for each significant factor explained that the parameters vary significantly between daytime and morning/nighttime. Results of T-test showed value difference between cloudy and sunny days. There was a linear correlation among temperature, pH, dissolved oxygen and oxygen reduction potential with greater diurnal fluctuation for all ponds. Earthen nursery ponds had statistically higher values of total dissolved solid, electrical conductivity and salinity and these parameters were highly correlated. Lower mean absolute percent error for best fitted linear regression model depicted good predictability of pH, electrical conductivity, dissolved oxygen and oxygen reduction potential for different time of a day. This research observed the fluctuation of water quality parameters at certain time interval thus opening up the scope for improvement in water quality at local management conditions.

Keywords: Aquaculture, water quality

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Farmers' appreciation of fodder trees and their preference by sheep in the Sudano-Sahelian zone of Burkina Faso

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Trees provide important functions to the rural population in the Sudano-Sahelian zone of Burkina Faso. During the dry season, they constitute an essential resource for feeding ruminant livestock. The objective of our study was to identify the fodder trees that are, according to farmers, the most palatable for small ruminants, and to confirm farmers' perception through a palatability test, within the EU-Horizon 2020 SustainSahel project (https://www.sustainsahel.net/). A total of 185 households in the Centre-West Region of Burkina Faso were interviewed using a structured questionnaire, followed by an on-station feeding choice experiment to assess sheep's preference for leaves of eight selected trees and shrubs assigned randomly to two blocks. Consumption time was taken as an indicator for the preference of a specific tree species and was observed during 30 minutes for two pairs of two sheep each per day, offered leaves of block 1 and 2, respectively, on alternate days. After a period of 8 days in total, all sheep had been exposed to all leaves twice.

According to the farmers, 15 tree and shrub species belonging to ten different plant families are highly palatable to small ruminants. The most frequently stated species are *Ficus sycomorus* (41 % of farmers), *Lannea microcarpa* (39 %), *Pterocarpus erinaceus* (33 %), *Khaya senegalensis* (23 %), *Azadirachta indica* (21 %), *Bombax costatum* (10 %), *Guiera senegalensis* (9 %) and *Ziziphus mauritiana* (6 %), which were subsequently tested in the sheep experiment. Here, the average consumption time was 3-fold, 3,5-fold, and 5-fold higher for leaves of *F. sycomorus* than for those of *P. erinaceus*, *K. senegalensis* and *L. macrocarpa* (block 1). In block 2, the average consumption time of leaves of *Z. mauritiana* and *B. costatum* was equally high, whereas leaves of G. senegalensis and *A. indica* were hardly consumed by sheep. It is therefore concluded that farmers have a fairly good knowledge of the fodder trees that are palatable to ruminant livestock. *F. sycomorus, Z. mauritiana* and *B. costatum* should be maintained and promoted as valuable livestock feed in this region.

Keywords: Burkina Faso, farmer knowledge, fodder trees, preference, sheep

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Livestock manure management and use by smallholder farmers, an assessment in Battambang province in Cambodia

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In Cambodia, soil depletion presents a serious threat for the agricultural production. Livestock manure can contribute with its organic content to a better soil fertility. However, not much is known about the manure management practices in Cambodia. Therefore the aim of the study is to generate basic knowledge about the farmers practices regarding farmyard manure management, including collection, storage and processing practices and the final use of the manure. Focus is laid on the management of cattle and chicken manure. In addition, some information was collected regarding pig manure. To gather data, a survey involving 68 semi-structured household interviews and seven key informant interviews were conducted. The target households and key informants were selected in six different villages in two communes in the district of Rottanak Mondol in Battambang province, located in the north-western part of Cambodia. To select the interviewed households, a non-random purposive multistage sampling was applied. The study was imbedded in a project about conservation agriculutre, which is implemented by the Swiss NGO Swisscontact in cooperation with the National University of Battambang (NUBB). The main results show that the majority of the respondents collects the cattle and chicken manure and stores it on simple heaps. The manure is stored on natural floor and not protected from weathering. Generally, the manure is not processed, only a small number of farmers did burn the manure and very few sold the manure to traders or cash crop producers. Around 70 % of the interviewed households apply the cattle manure on their own crops (mainly rice and cassava). For chicken manure it was 83 % of the chicken keeping households and chicken manure was used mainly in the home garden. Main reasons for not using the manure are time consuming and hard work needed to collect, transport and apply the manure compared to the easy application of chemical fertiliser. Secondly, some respondents were complaining about more weeds growing in the field after applying manure. Especially storage and processing practices have potential for improvement. By for example protecting the storage sites from weathering with a simple roof the loss of nutrients could be reduced. Furthermore, composting of manure would diminish its volume and make the transport and application easier. By improving the present practices some of the problems mentioned by the respondents as reasons for not applying manure on their crops would already be solved.

Keywords: Cambodia, cattle manure, chicken manure, livestock waste management, soil fertility, Southeast Asia

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Nutrition, performance and management of animals

Oral Presentations

Posters

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Assessment of *in vitro* ruminal fermentation characteristics, methane (CH_4) production, and associative effects between low-quality roughages and protein supplements

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To evaluate the *in vitro* fermentation, CH_4 reduction, and associative effects between low-quality roughages and protein feeds, rice straw (RS), German grass (GG), Napier silage (NS), and maize silage (MS) were incubated alone or after replacement by Ipil-ipil or Gliricidia at levels of 10 %, 20 %, 30 %, and 40 %, respectively, using the Hohenheim Gas Test. An amount of 200 mg was incubated with rumen fluid-buffer solution for 72 h to measure gas production (GP) and calculate organic matter digestibility (dOM) and metabolisable energy (ME). Additionally, 120 mg of feed were incubated for 24 h to determine the CH_4 concentration in the GP. Associative effects between feed ingredients were calculated by comparing the measured and estimated values of the composite feed and the estimated values were the weighted mean of the values of fermentation of the individual feeds. The GP24 and rumen fermentation rate increased ($p < 0.05$) as the level of Ipil-ipil added to RS was increased. Increasing the Ipil-ipil level resulted in a gradual increase in dOM and ME ($p < 0.05$) of the mix, reaching maximum values (59.1 % and 7.60 MJ ME kg^{-1} DM, respectively) and maximum reductions in CH_4 concentration and CH_4/dOM (6.89 % and 11.7 %, respectively) compared to the control, when Ipil-ipil was added at 40 % DM. When Ipil-ipil was added at 30 % to NS, the same trend was observed for dOM and ME (56.5 %, and 7.55 MJ ME kg_{-1} DM, respectively) and CH_4 concentration and CH_4/dOM (5.32 % and 13.3 %, respectively). No significant interaction was observed between Ipil-ipil and good quality roughages like GG and MS. The opposite trend was found for GP24, dOM, ME, and CH_4 production when an increasing level of Gliricidia was added to the roughages. A positive associative effect was obtained for all mixed treatments ($p < 0.05$) and showed a maximum when 40 % Ipil-ipil was added to RS and 30 % Ipil-ipil to NS. In conclusion, based on *in vitro* rumen fermentation, CH_4 production, and associative effects, adding Ipil-ipil to low-quality roughages is superior to Gliricidia and demonstrated promising results and ranked as follows: RS + 40 % > NS + 30 % Ip > MS + 30 % Ip > GG + 10 % Ip.

Keywords: Associative effect, leguminous fodder, rumen digestion

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Predicting microbial protein synthesis of cattle under tropical conditions

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This study aims to identify an accurate method for estimating rumen microbial protein synthesis (MCP) by comparing five methods to estimate MCP and three approaches to predict fecal bacterial and endogenous debris nitrogen excretion (BEDN) against measured BEDN. A dataset was compiled (n=95) from three feeding trials conducted with steers and heifers under typical tropical feeding situations. Using the total collection method, fecal samples were collected, and pooled samples were subsequently used to estimate the BEDN excretiona. MCP1 was predicted from urinary purine derivatives excretion. MCP2 was derived from estimates of fermented metabolisable energy and MCP yield. MCP3 was derived from estimates of fermented organic matter and the proportion of concentrate in the diet. MCP4 was derived from metabolisable energy and a constant MCP yield of 10.1 g MCP MJ^{-1}. MCP5 was derived from estimates of microbial and feed crude protein determined *in vitro* and rumen undegradable crude proteind. BEDN excretion was predicted assuming a MCP proportion of 0.36 (BEDN1), 0.15 (BEDN2), and 0.11 (BEDN3). From the three proportions of MCP that represent BEDN excretion and the five methods used to predict MCP synthesis, 15 predictions of BEDN excretion were derived. Accuracy between measured and predicted BEDN excretion was evaluated using the root mean square error (RMSE expressed as % of the measured BEDN). Differences between MCP methods were evaluated with a Tukey test. Means of MCP1 and MCP2, MCP3 and MCP4, and MCP3 and MCP5 were the same ($p > 0.05$), while for the remaining comparisons, the means differed ($p < 0.01$). The estimation of BEDN excretion was more accurate when BEDN2 was combined with MCP3 (RMSE of 45 %) or MCP4 (RMSE of 43 %) than in other combinations (RMSE from 50 to 155 %). It can be concluded that BEDN2 predicts measured BEDN more accurately than other approaches. Measured BEDN is predicted more accurately when using MCP3 and MCP4 than MCP1, MCP2, and MCP5. Nonetheless, further research is required to evaluate if these results apply to lactating cows under tropical conditions.

Keywords: Cattle, fecal excretion, microbial protein synthesis

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Feed additive effects on Awassi ewe's performance and their nursing lambs

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To study the effect of feed additive on the performance of Awassi ewes and their nursing lambs, thirty Awassi ewes were individually housed with their nursing lambs and randomly assigned into three groups (10 ewes treatment-1). A well-balanced feed additive premix (mineral and vitamin) for sheep was prepared for this study by Al-Estesharia and add to the diet at 2.5 %. Control (CON) were ewes fed diet with commercial premix added at 0.1 % of the diet; Premix (P2.5) group were ewes fed well-balanced premix at 2.5 % of the diet and premix plus (P2.5+) group were ewes fed well-balanced premix at 2.5 % along with balanced energy, protein diet. All groups offered *ad libtium* 20 % as wheat straw and the rest (80 % of the diet) as concentrate. Concentrate ingredients for all groups consist of corn grains, barley grains, soybean meal and wheat bran. The quantity of feed offered were monitored and gradually increased to make sure that ewes have free access to feed at all time. The quantity of feed offered to ewes were calculated and the next-day refusals were recorded. Lambs body weight were measured weekly, weaning weight were measured at 70 day and average daily gain (ADG) were calculated. Individual milk yield and components were measured biweekly for the first 10 weeks of lactation. No significant difference in average milk yield between CON and P2.5 groups. On the other hand, average milk yields in P2.5+ group were significantly higher ($p < 0.05$) compared to other groups (871 g vs. 717.3 and 680 g of milk for P2.5+, CON, P2.5, respectively). No significant differences were found in milk component. Milk protein, fat, lactose and total solid were not affected by adding well balanced feed additive to the diets. Lambs in P2.5+ and P2.5 had higher ($p < 0.05$) weaning weight and ADG compared to CON group. As a results, well-balance diet along with feed additive up to 2.5 % of the diet not only increase milk production in Awassi ewes, but also improve the performance of their nursing lamb.

Keywords: ADG, Awassi ewe, feed additive, milk yield, nursing lambs, weaning weight

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Growth rate of male Bali cattle (*Bos javanicus*) fed leucaena based diets with increasing levels of cassava

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To improve protein content of cattle feeds, several initiatives on the planting and use of leucaena (*Leucaena leucocephala*) for cattle fattening have been conducted in eastern Indonesia, resulting in extensive leucaena planting and use for cattle fattening in the region. Most farmers feed leucaena (19–28 % CP) as a single diet, that results in excessive protein supply. If balanced with an external energy source such as cassava (*Manihot esculenta*; 12-15 MJME kg DM^{-1} it would benefit both the use of protein and extend limited supplies of leucaena for feeding fattening bulls. An experiment using 30 growing male Bali cattle (*Bos javanicus*) with initial live weight of 164±1.8 kg was conducted to determine the optimum ratio of leucaena and cassava for live weight gain (LWG) and feed for gain ratio. Five animals were allocated to one of six experimental treatments i.e. 20 % rice straw + 80 % leucaena hay + mineral mix (A), 20 % rice straw + 65 % leucaena hay + 15 % cassava chip + mineral mix (B), 20 % rice straw + 50 % leucaena hay + 30 % cassava chip + mineral mix (C), 20 % rice straw + 35 % leucaena hay + 45 % cassava chip + mineral mix (D), 20 % rice straw + 20 % leucaena hay + 60 % cassava chip + mineral mix (E) and 20 % rice straw + 5 % leucaena hay + 75 % cassava chip + mineral mix (F). Feed intake declined when the cassava was fed at the level of more than 45 % of the diet. Rumen pH values in all treatments were within the normal range (6.2–6.5). The LWGs for each treatment were 0.49±0.06, 0.54±0.06, 0.58±0.12, 0.68±0.06, 0.38±0.06 and -0.11± 0.06 kg ha^{-1} for the animals fed diets A, B, C, D, E and F respectively and treatment D (45 % cassava) reached the highest values. The respective feed for gain ratios for diets A, B, C, D and E were 9.68±1.93, 8.37±0.88, 9.93±5.45, 7.68±0.76 and 12.13±3.34 kg feed DM/kg LWG, with corresponding income over feed cost (thousand IDR/day) of 14.77±0.71, 17.95±0.51, 20.10±1.35, 24.48±0.635 and 10.41±6,466. In conclusion, the best LWG and income were reached when leucaena was 35 % and cassava chip 45 % of the diet.

Keywords: Bali cattle, cassava, growth rate, leucaena

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Effects of inclusion of guava fruit processing by-product in broiler chicken diets on performance

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The use of fruit wastes as animal feed can contribute to meeting the feed insufficiency existing in most developing countries and simultaneously help mitigate environmental pollution and green gas emission from these wastes. A study to determine the effects of the inclusion of guava fruit processing by-product in broiler chicken diets on performance was carried out. Ripe pink guava fruits were crushed and sieved to separate the pulp from the guava by-product consisting of peels, seeds, and other fibrous content. The guava by-product was sun-dried and included in isocaloric and isonitrogenous broiler chicken diets at 4 different levels 0 %, 2.5 %, 5 % and 7.5 % in both starter and finisher rations. One hundred and sixty (160) day-old cobb-500 broiler chicks obtained from a reputable commercial hatchery were randomly allocated to the four diets and replicated four times with ten birds in each replicate. The feed intake and body weight were monitored for 42 days. The feed conversion ratio for the period was determined.

The sun-dried guava by-product had mean 88.51 % DM, 46.46 % CF, 5.41 % CP, 6.32 % EE, 3.1 % ash, and 38.71 % NFE. The 5 % inclusion level resulted in the highest average daily feed intake (62.47 g d^{-1}) compared to the 0 % (59.03 g d^{-1}) and the 2.5 % (59.21 g d^{-1}) that were similar. The ADGs were similar for inclusion levels 0 %, 2.5 %, and 5 % (56.53, 54.88, 61.02 g d^{-1} respectively). The average daily feed intake (FI) and daily weight gain (ADG) were lowest ($p < 0.05$) for the 7.5 % inclusion level (51.20 g d^{-1}, 45.68 g d^{-1} respectively) compared to the other diets. The FCR (1.58, 1.66, 1.64 and 1.72 (0, 2.5. 5 and 7.5 % respectively) was not influenced by the level of inclusion of guava processing waste in the diets. It was concluded that the guava processing waste could be included up to 5 % in broiler diets without any adverse effects on performance thus contributing to food security by reducing the food: feed competition.

Keywords: Broiler chicken, feed intake, guava by-product, performance

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Use of natural zeolite in broiler diet and its effect on performance and carcass traits

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This experiment was carried out to determine the effects of natural zeolite on performance, carcass traits and the content of blood protein and calcium in broilers. 240 Ross unsexed broiler chicks (one day old) were allocated into one control treatment without natural zeolite and 3 zeolite treatments (with 0.5 %, 1 % and 1.5 %) respectively, and 5 replicates and 12 birds each. The local natural zeolite (NZ) used in this experiment contains 92 % clinoptilolite. Birds were kept in litter floor pens with the same size in a deep litter system. The experimental diets were based on maize-soybean meal and were formulated to meet the nutrient requirements of broiler. Results indicated a significant effect ($p < 0.05$) on body weight and feed conversion ratio in the entire period by adding 1.5 % NZ comparing to birds with 0.5 % or 1 % NZ and without zeolite (control birds). But there were no significant differences observed in feed intake and carcass yield among all treatments in this study. Also, the addition of 0.5 and 1 % of natural zeolite had no effect (P≥0.05) on performance parameters. However, adding of 1.5 % zeolite increased significantly ($p < 0.05$) the weight of breast, edible organs (heart, gizzard, liver) and the weight of tibia. The zeolite addition did not affect the blood protein, but the content of blood calcium was increased significantly by 1.5 % zeolite in the diet. In conclusion, adding of 1.5 % natural zeolite to broiler diet improved the growth rate, feed conversion ratio, tibia weight and increased the blood calcium concentration and could be added to broiler diet in this percentage.

Keywords: Carcass, growth performance, tibia, zeolite

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Influence of nanoencapsulated essential oils on productive parameters of broilers

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The studies were carried out using broiler chickens of the Cobb 500 breed in the vivarium of the National University of Trujillo, Peru; with the objective to determine the effects of nanoencapsulates essential oils of guanabana, lemon and Eucalyptus on their performance. One hundred one-day old chickens were divided in five treatments, T0 (control): 70 g of Halquinol t^{-1} feed; T1: Guanabana 33.4 %, lemon 33.3 %, Eucalyptus 33.3%; T2: Guanabana 50 %, lemon 25 %, Eucalyptus 25%; T3: Lemon 50 %, guanabana 25 %, Eucalyptus 25%; T4: Eucaliptus 50 %, guanabana 25 %, lemon 25%; with doses of 75 g t^{-1} feed. The animals were fed ad libitum, the nutritive density of the feed was in accordance with the recommendations of Cobb-Vantress. The Halquinol (T0) was fed from 1–35 days of age. The T1 chickens had the highest body weight at 42 days and average daily gain compared to the results of the other groups. While the chickens of the control group (T0) had the lowest body weight and lowest average daily gain as compared to all other treatments. Feed intake and feed conversion also differed between groups. Although the T1 chicks consumed more feed during the feeding period, the feed conversion ratio was the lowest. The highest breast output was noted in the experimental groups T1 and T4 and exceeded the control group by 2.6 % and 2.4 %, respectively. Also, a positive and significant effect of nanoencapsulated essential oils on the yield of eviscerated carcasses and the yield of breast, which is the most valuable part of broiler meat, has been established. It can be assumed that it is the combined effect of several essential oils that has a positive effect on overall productivity and meat performance.

Keywords: Broilers, essential oils, performance, poultry

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An analysis of adoption of crossbred poultry and its impact on well-being among rural poultry-keeping households in Ethiopia

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Crossbred poultry adoption has recently been increasing in Ethiopia. Growing efforts to achieve improved family poultry and its promises signify the importance of adoption and livelihood impact studies of crossbred poultry adoption. Employing the baseline survey data of the second panel Ethiopian Socioeconomic Survey (ESS), this paper studies the determinants of crossbred poultry adoption and its significance for household well-being. The paper tests well-being outcomes of crossbred poultry adopters against that of local breed holders. To deal with endogeneity, methodological approach resorts to matching methods employing Inverse-Probability-Weighted Regression Adjustment (IPWRA) technique. Results show that female poultry managers, constrained in other productive livelihood options, are more likely to adopt crossbred poultry. Households that are relatively wealthier in terms of human resources, assets, access to food, and dwelling conditions are more inclined to adopt crossbred poultry. Access to advisory services, experience with other crossbred animals, and the size of the agricultural land are among other significant determinants of crossbred poultry adoption. Concerning well-being outcomes, crossbred poultry adoption increases egg sales and revenue. The sample does not provide sufficient evidence to conclude any impact on food, non-food consumption, or investment in children's human capital. Overall, the average flock size and revenue from egg sales are relatively small. Nevertheless, predicted revenue from an extra layer chicken in crossbreed adopting households triples the predicted revenue from egg sales in local breed keeping households. Increasing average flock size twice by crossbred birds could generate an annual revenue equal to at least 10 % of yearly consumption expenditure. These results suggest that flock sizes in rural family poultry production should be increased with more crossbred birds to sustain livelihoods significantly.

Keywords: Crossbreed, Ethiopia, impact, IPWRA, matching, poultry

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The economic feasibility of insect-based feed for commercial poultry production in Kenya

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Integrating insect protein in commercial feed formulation for livestock production is not only expected to reduce pressure on strained natural resources but to also contribute to food and nutrition security, improve farmers' livelihoods and to promote economic growth. Stakeholder involvement is imperative for the realisation of the stated milestones. The study conducted multiple field experiments with the involvement of smallholder farmers for a period of nine weeks. Specifically, we evaluated the effects of partial and total replacement of fishmeal with black solder fly (*Hermetia illucens*) larvae (BSFL) at 25 %, 50 %, 75 % and 100 % BSFL inclusion on the performance traits of 280 broiler chicken and the economic impact. The live weight, average body weight gain (ABWG), feed intake and feed conversion ratio (FCR) were captured. Economic marginal analysis and sensitivity analysis at 20 % and 50 % increases in feed cost were computed. We found that there are no significant differences in the live weight and the ABWG of the birds across all diets. Partial and total replacement at 75 % recorded the highest feed efficiency of 2.0 against 2.5 FCR for the control diet. The most profitable diet was 25 % BSFL with 147 % rate of return which is 112 % less than that recorded for conventional feed, and a gross margin of US$ 8.25 against US$ 7.79 of the control diet. At both 20 % and 50 % feed price increments, partial replacement at either 25 % or 75 % BSFL remain profitable by at least 74 % compared to the control diet. No doubt that insect protein is an economically feasible feed ingredient for commercial livestock production and consequently for food security and improved livelihoods.

Keywords: Economic, environment, insect, kenya, profitability, smallholder farmers

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Growth performance of Amur catfish (*Silurus asotus*) in various aeration rates in an indoor BFT system

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The development of biofloc technology (BFT) as a sustainable and environmentally friendly aquaculture technology includes discovering new species suitable for it. Amur catfish (*Silurus asotus*) is an important freshwater fish in East Asian countries that has the potential to be reared in BFT system. This study evaluates the growth performance of Amur catfish in an indoor BFT system with aeration rates as variable. Twenty catfish with an average weight of 4.17± 0.20 g and length of 8.11±0.32 cm were stocked in eighteen aquaria. Six treatments i.e., 2lpm, 3lpm, 4lpm, 5lpm, 6lpm, and 7 lpm aeration rates with equivalent surface area loading rates 43, 64, 85, 107, 128, and 149 $m^3/m^2/d$ were designed in triplicates. Fish were fed 5 % of body weight and dextrose was added at a 15:1 C:N ratio. Dissolved oxygen, temperature, and pH were monitored twice daily. Total ammonia nitrogen and nitrite along with total suspended solids and floc volume were monitored once a week. Growth was monitored after week 4 and week 8. DO and the temperature was maintained at >8ppm and -24 °C respectively. The pH was statistically higher in the 128, 149, and 107 $m^3/m^2/d$ as compared to the 43, and 64 $m^3/m^2/d$ treatments. Inorganic nitrogen species were not significantly different while solids were higher at higher aeration rates. Survival of catfish was low and among the treatments with fish in 2lpm aquaria having high mortalities as early as 5^{th} week of the experiment and not exceeding 58 % for all treatments. Individual weight and length gain, specific growth rate, condition factor, total weight gain, and FCR, were not significantly different among the treatments except for 43 $m^3/m^2/d$ tanks (which exhibited a low survival rate). Aeration plays an important role in the management and control of biofloc in BFT systems, however, other factors may have influenced the growth performance of catfish in this study such as cannibalism and floc properties.

Keywords: Biofloc, catfish, growth

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Para-rubber seed kernel fermentation using *Aspergillus oryzae* and *Saccharomyces cerevisiae*: Targeting for aquafeed

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Para-rubber is an important economic crop in Thailand, having cultivation area of up to 5.36 million acres and yielding a lot of rubber seeds. However, only a small portion of the para-rubber seed kernels (PRSK) is utilised and the remaining are left to spoil. The PRSK can be utilised as an animal feed ingredient if appropriate improvement processing methods are applied. Fermentation with eukaryotic microorganisms is a candidate method to enhance the nutritional value of the PRSK. This study therefore aimed at increasing nutritional value of PRSK by employing two-step fermentation with fungi, *Aspergillus oryzae* and yeast, *Saccharomyces cerevisiae*, respectively. The PRSK, original protein contents of 28.89 $\pm$ 0.03 % dry matter (DM) basis, was firstly boiled to remove cyanide which naturally contained in the seeds, then the oil was extracted using 95 % ethanol. The extracted samples were subsequently fermented with *A. oryzae* at concentrations of 0, 1, and 2 %, with distilled water added at 20, 40, 60, and 80 % (w/v), respectively for 192 h. The best combination of *A. oryzae* and distilled water levels was identified based on obtained proximate composition in the samples. The PRSK fermented with 1 % *A. oryzae* and 40 % distilled water (w/v) gave the best results which was then used for further fermentation. The second step was performed in a series of tests using *S. cerevisiae* yeast at 0, 2, 3, 4 and 5 %, sugar 0, 0.2, 0.3, 0.4 and 0.5 %, distilled water 0, 50, 66.67, 83.33 and 100 % (w/v) at 0, 24, 48, and 72 h, respectively, to obtain the suitable combinations of the factors. The results showed that 5 % *S. cerevisiae*, 0.5 % sugar, and 100 % distilled water (w/v) for 72 hours was a suitable factor combination for fermenting PRSK to enhance protein level at 45.71 $\pm$ 0.14 % DM basis. It can be concluded that this two-step processing method using *A. oryzae* and *S. cerevisiae* as reported above can be used to improve the nutritional value of PRSK that could be used as an aquatic feed ingredient to reduce feed cost for aquaculture production and ultimately benefit aqua-farmers.

Keywords: Aquafeed ingredient, *Aspergillus oryzae*, para-rubber seed, *Saccharomyces cerevisiae*, suitable fermentation conditions

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Impact of feeding sweetpotato vines silage on growth and carcass quality of pigs in Uganda

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In Uganda, pig farming is an important livestock activity. The high cost, poor quality and the lack of feed remains the greatest constraint. Commercial concentrate feeds are costly, of uncertain quality and unavailable in the rural areas. Local feed ingredients e.g., sweetpotato residues are cheap but limited and fluctuates seasonally. There are knowledge gaps to preserve and formulate complete forage-based balanced for supplementing pigs. The objective of this research was to assess the impact of feeding sweetpotato vines (SPV) based silage on growth rates and carcass quality of growing pigs in Uganda. We addressed the question 'To what extend can sweetpotato silage be economically included in a commercial diet without significantly affecting growth rates, and carcass quality of growing pigs?' The study included 48 pigs (mean initial body weight of 23 $\pm$ 0.5 kgs). The experiment had two diets: sweetpotato silage (80 and 60 % inclusion) and maize-soybean meal (20 and 40 % replacement) giving a total of 4 treatments. Pigs were randomly allotted to treatments in groups of four. Pigs were weighed initially and subsequently on a weekly basis for 12 weeks. Feed offered and refusals were measured daily. Two male and female pigs/treatment were slaughtered to evaluate carcass quality (90 days). Mean body weight (BW) of pigs did not differ between farmer practice (100 % SPV) and 80:20 SPV:MSN diet. However, the BW differed significantly between 60:40 SPV:MSN diet and the commercial diet (100 % MSN), (90 days), ($p < 0.05$). As expected, the average daily gain (ADG) increased with increased level of commercial diet. The 60:40 SPV:MSN diet gave the highest ($p < 0.05$) ADG relative to 100 % SPV. The 100 % SPV diet had lowest cost but highest cost per live weight gain ($2.29). Conversely, the MSM diet had the lowest cost per live weight gain ($0.48) but more costly diet. Compared to 100 % SPV, the 60:40 and 80:20 SPV:MSM diet rations were more economical, at $0.52 and $0.57 per live weight gain respectively. The 60:40 SPV:MSM diet was 32 % less expensive to produce/kg of carcass weight relative to 100 % SPV. We concluded that pigs grow well on the 60:40 SPV:MSM diet.

Keywords: Feeding, pig diets, pig production, sweetpotato silage, sweetpotato vines

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Potential applications of amino acids supplementation for captive breeding of cervids in South-East Asia

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Deer farming is a thriving industry for venison, trophy hunting, and especially velvet antler which is seen as the main product for traditional medicine in Southeast Asia. Feeding and nutrition are important factors for improving production performance, especially protein and amino acids (AA), as they are the main components of all tissues. In deer nutrition, during velvet and antler growth deer require 16 % - 22 % crude protein. It is also very crucial for supporting growth of young, reproduction, pregnancy, and lactation. However, feeding protein and AA in tropical climate is challenging because of hot environments which can limit intake and poor digestibility from protein sources in this area. Therefore, improving AA balance via supplementary feeding can be an effective alternative to fulfil protein requirements. Despite the importance and the potential of AA in cervid nutrition, knowledge is still very limited compared to other ruminant livestock.

Only a few studies on AA supplementation(Lysine, Methionine, Arginine) have been carried out on cervids. These have shown an increase in growth performance such as body weight, feed intake, nutrient digestibility, carcass weight, body condition scores, meat quality, rumen health, and especially velvet (velvet yield) and antler growth (antler burr perimeter, weight, length, mineralisation). Therefore, this review provides an overview of the current status of deer farming and utilisation, and the effects of AA supplementation on growth and production in ruminant livestock and cervids, based on approximate metabolic body weights. Furthermore, the potential effects of AA that have not yet been studied in cervids is also discussed, especially oriented to benefit deer farming under tropical climate conditions.

Keywords: Antlers, deer, feed additives, protein, ruminants, venison

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Effect of willow silage ecotypes on carcass characteristics and meat quality of Black Mountain kids

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The objective of this study was to evaluate the effect of willow silage from different ecotype on carcass characteristics and meat quality of Black mountain kids in Jordan. Twenty-eight male black mountain kids were randomly assigned to four groups with different ecotype of willow silages; Control group were kids fed wheat straw, Shoubak, Madaba and Nazareth groups were kid fed willow silage from ecotype. Concentrate were formulated accordingly to each diet to fed iso-caloric, iso-nitrogenous rations. Black mountain kids were fed high concentrate diet (20:80, F:C ratio) for 90 days after which 3 kids from each group were sacrificed to study the effects of willow silage from different ecotypes on carcass characteristics and meat quality in goat meat. Hot carcass weight, cold carcass weight, dressing percentages were not affected by feeding different willow silage ecotype. Weight of internal organs were all unaffected by feeding willow silage from different ecotypes except for spleen weight Madaba group were higher ($p < 0.05$) compared to Control and Shoubak group, while Nazareth group were intermediate. Kidney fat for control lambs was significantly ($p < 0.05$) higher (395 g) compared to willow silages groups (238, 233 and 223g, for Madaba, Shoubak and Nazareth, respectively). As a percentage of cold carcass weights, control had significantly ($p < 0.05$) lighter racks cuts compared to other silage groups. Although the depth (A) of Longissimus dorsi muscle were significant ($p < 0.05$) lower in control kids, total loin area was not significant. In conclusion, silages from different ectypes of willow had similar effects on carcass characteristics of black mountain kids, however feeding willow silage decrease the deposition of kidney fat and produce heavier rack cuts compared to kids fed wheat straw as a source of roughages.

Keywords: Carcass characteristics, meat quality, willow (*Salix* spp.) ecotypes, willow silage

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Effect of *Lactobacillus rhamnosus* C6 inoculation on fermentation quality and rumen degradability of maize cob and hush silage

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The objective of this study were to evaluate effect of *Lactobacillus rhamnosus* C6 inoculation on fermentation quality and rumen degradability of maize cob and hush silage. *L. rhamnosus* C6 were isolated from rumen fluid of Thai native cattle. The isolates was grow in nutrient agar (NA) plate at 37°C for 48 hours in anaerobic condition. Maize cob and hush silage were divided 2 groups as control and supplemented with *L. rhamnosus* C6 with 10^6 cfu g^{-1}. Silage was collected at 21 of fermentation. The fermentation quality was evaluated by pH measurement and VFA analysis. The chemical compositions were analysed by proximate analysis and detergent fiber method was employed to determine fiber compositions. Ruminal degradability was determined using *in vitro* gas production technique. Ruminal fluid was obtained from 4 rumen fistulated Thai native cattle. Gas production was recorded after incubation at 2, 4, 8, 10, 12, 24, 48, 72 and 96 hr. The pH value of maize cob and hush silage inoculated with *L. rhamnosus* C6 were lower than control group. Lactic acid concentration was higher in inoculated groups. Maize cob and hush silage inoculated with *L. rhamnosus* C6 showed significantly lower NDF, cellulose and hemicellulose contents than control group. Moreover, gas production at 48 and 72 hr after incubation was significantly greater in inoculated groups. It could be concluded that maize cob and hush silage inoculated with *L. rhamnosus* C6 had better quality fermentation than natural fermentation as *L. rhamnosus* C6 stimulated the fermentation process and accelerated lactic acid production, resulting in a sharp drop in pH and faster ruminal degradability after 48 hr of incubation.

Keywords: Fermentation quality, *Lactobacillus rhamnosus* C6, maize cob and hush silage, rumen degradability, Thai native cattle

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Suitability of improved forage varieties for dairy cattle in Kenyan semi-humid and semi-arid agroecological zones

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Feed is a major component accounting to over 60 % of the cost of milk production. The dairy feed sub-sector in Kenya faces challenges such as high cost of production, lack of quality forage seeds, lack of feeding data, poor feed storage facilities, small landholdings and lack of investment potential. The average milk yield of intensive feeding systems in Kenya is about [8] kg per cow and day, which despite additional concentrate supplementation, is still below the potential daily milk yield of up to 10 litres from cattle fed on well managed quality forages alone. This study aimed to assess the potential of newly introduced improved forage varieties grown under different agroecological farmer-managed conditions, to meet the nutrient needs of cows.
Four groups of forages; tropical grasses (*Brachiaria* and *Panicum*), tropical legumes (desmodium and lablab), temperate grasses and forages (chicory, oats and rye grass) and one temperate legume (lucerne) were assessed in four locations in two agroecological zones (AEZ). Farmer-managed plots of 50 m^2 were made for each forage type on four farms (one from each location). The biomass yield was estimated from 1 m^2 of each, while a representative sample of the harvested material was analysed for nutritive value.
Results from the first cuts show that tropical grasses took four months longer to establish compared to other forages in the semi-humid AEZ. Nevertheless, once established, the biomass of tropical grasses at one cut, was significantly higher than the other forages. Protein and Metabolizable Energy content of temperate grasses and forages was high and NDF content relatively low and comparable to that of lucerne. For the tropical grasses these were respectively lower (below 20 % and 50 % respectively) and NDF higher (above 50 %).
Temperate grasses and forages thrived better in the semi-humid AEZ while tropical forages performed better in the semi-arid AEZ under irrigation. The performance of all legumes was poor though slightly better in the lower altitude semi-arid AEZ with irrigation and a higher soil pH. An economic analysis of the costs and benefits of growing each forage in each of the agroecological zones is ongoing and final results for these trials will also be available.

Keywords: Grasses, legumes, metabolisable energy

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Perception of livestock keepers about woody fodder in the diet of sheep in two rural communes in Koulikoro region, Mali

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The Sahel is one of the areas of Africa where livestock farming is practised essentially in a traditional and extensive way. However, the management of pastoral resources raises the environment issues that must be quickly addressed by providing scientific and technological supports to the communities. Within the EU-Horizon2020 project SustainSahel (https://www.sustainsahel.net), this study aimed at better understanding the perception of livestock keepers about the utility of local woody fodder plants in sheep production systems. To this end, an interview-based survey was carried out in five villages in the communities of Méguétan and Doumba in the Koulikoro region of Mali. One hundred and thirty-one livestock keepers were randomly selected for personal interviews. In addition, 15 key stakeholders (village leader) were interviewed, and one focus group discussions (FGDs) were conducted with at least twenty agro-pastoralists per FGD in order to complete the information. The survey data has been captured in the Excel software and analysed using the software SPSS statistics. The results showed that more than three quarters of the respondents practice mixed crop-livestock farming, while the remaining were pure pastoralists. Nearly all livestock keepers (95 %) used woody fodder plants; in addition 85 %, 56 % and 47 % used grasses, agro-industrial by-products, and commercial feedstuffs. The most widely used browse species for feeding sheep were *Pterocarpus lucens, P. erinaceus, Ficus sycomorus, Entada africana*, and *Khaya senegalensis*. These trees were exploited by pruning (100 % of those surveyed), shaking fruits (11 %) or picking fruits (5 %). Woody fodder is mostly used during the dry season (95 %) and at the beginning of the rainy season (72 %). These results show the importance of woody species as feed for sheep during the dry season when grasses become scarce and of poor quality; in a further step the nutritional value of the most widely used woody species needs to be explored to assist farmers in formulating adequate rations.

Keywords: Livestock keepers, Mali, perception, sheep, woody fodder

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Inclusion of cinereous cockroach flour in the feed of bullfrogs

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The bullfrog (*Lithobates catesbeianus*) is carnivorous in the post-metamorphic phase and needs food with high protein content, so a commercial fish food for carnivorous fish is used with high protein level (40–45 %), and it can be mixed or not with housefly larvae. Numerous species of insects are being tested for animal feed, including the cinereous cockroach (*Nauphoeta cinerea*), which has an average protein content of 62.2 % and a lipid content of 27.6 %. So, this work aims to evaluate the effect of the inclusion of cinereous cockroach flour in bullfrogs diet on performance. For this, 32 bullfrogs were housed in 4 concrete semi-flooded pens - Anfigranja production system (1.75 m × 1.72 m). The average water temperature was of the 25.5 $\pm$ 3.4 °C during the experimental period. The bullfrogs were acclimated for six days were weighed on an electronic scale (initial weight of 124.1 $\pm$ 48.12 g) and distributed in a completely randomised design in three treatments, with eight repetitions. The treatments consisted of the addition of Cinereous Cockroach Flour (CCF-UFMG- Brazil) in the proportion of 0, 25 and 50 % in the commercial food. The bullfrogs were fed twice a day (*ad libitum*) for 36 days. Food consumption was calculated by the difference between the food offered and the leftovers. At the end of the experimental period was evaluated the frogs daily feed intake; weight gain (WG); specific growth rate (SGR) and feed conversion (FC). The addition of CCF to the bullfrog diet did not affect ($p > 0.05$) the productive performance variables initial weight, final weight, WG and SGR. However, the average feed intake in the period (grams for day), linearly reduced (y= 186.4583 – 0.8800, R^2= 0.995, $p < 0.01$) with the addition of CCF. Linear reduction trend ($p = 0.06$) was observed for WG (51.2, 65.5 and 81.4 g) and SGR (1.8, 2.3 and 2.8 g.day^{-1}) with the addition of CCF at 0 %, 25 % and 50 %. The inclusion of cinereous cockroach flour, in these experimental conditions, allowed the reduction of feed consumption without affecting the performance parameters.

Keywords: Biochemical profile, insect proteins, *Lithobates catesbeianus*, sustainably

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Availability and use of woody fodder in the diet of small ruminants in the silvo-pastoral zone of Senegal

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In extensive Sahelian livestock systems, woody fodder accounts for 40–50 % of dry season livestock feed. Within the EU-Horizon2020 project SustainSahel (https://www.sustainsahel.net), this study aimed to characterise the perception of pastoral communities on availability and use of woody fodder in small ruminants' diet in the silvopastoral zone of Senegal. To this end, an ethnobotanical survey of 81 agropastoralists was conducted in 19 villages of the Ouarkhokh commune in July 2021. Its results allowed listing the main woody species available and their uses in the diet and health care of small ruminants. About 81 % of the surveyed farmers use the available woody fodder species. According to them, the species most frequently consumed by small ruminants are *Balanites aegyptiaca*, *Acacia raddiana*, *Guiera senegalensis*, *Faidherbia albida* and *Adansonia digitata*. These species were then used in a feeding trial at the Dahra zootechnical research centre of the Senegalese Institute for Agricultural Research (ISRA-CRZ/Dahra), between November and December 2021. The objective was to test the preference of the local Peul peul sheep breed for the woody species pre-selected by the interviewed agropastoralists. The trial was carried out in a completely randomised design with woody fodder as diet supplement allocated to four male sheep aged 18 months with an average weight of 28 kg. It included an adaptation phase of four days during which the animals received the basic ration, a second phase during which the sheep were fed with fresh leaves for five days, a third transition phase of four days, a last phase during which the sheep were fed with air-dried leaves for five days, and two closing days to determine the animals' weight gain. For both the fresh leaf and the air-dried leaf phase, the results of the experiment showed a highly significant difference in sheep's preference of leaves ($p < 0.001$). The forage species most consumed by the animals were *Acacia raddiana* and *Balanites aegyptiaca* in fresh and dry stage. Given the predominant role that woody fodder plants play in the feed supply of extensive livestock systems, their preservation and sustainable use is essential for the feed supply of livestock on natural pasture during the dry season.

Keywords: Dry leaves, feeding trial, fresh leaves, Senegal, sheep, silvo-pastoral zone, woody fodder

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Cattle production pattern and feed resources in the derived Savannah ecological area of Oyo State, Nigeria

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Forage availability for ruminant production is the main challenge, especially in the dry season. The low qualitative and quantitative forages necessitate looking inward for other feed resources (FR) for cattle production at the system level. The study tried to investigate cattle distribution patterns and FR in the derived savannah ecological area of Oyo State, Nigeria. A multi-stage sampling technique used to elicit information from purposively selected one hundred and eighty respondents in six locations; Akinyele, Ido, Egbeda, Ona-ara, Oluyole, and Ibarapa East. The distribution of cattle farms were taken with global positioning systems (GPS), and cattle herd size (Total Livestock Unit, TLU) was recorded. The GPS data were transferred into the ARC-GIS software and processed with the ARCGIS model 10.0. Samples of (FR) fed to cattle were collected and analysed for chemical compositions: crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) with near infra-red reflectance spectroscopy (NIRS). A mixed feed global calibration Model using the software package WIN ISI. Data were analysed using descriptive statistics.The cattle production and distribution pattern (TLU) were 100, 70, 6, 4, 3, and 2 for Ido, Ibarapa East, Egbeda, Ona-ara, Akinyele, and Oluyole local government areas, respectively. The available FR were natural forages, crop residues, fodder planted, feed ingredients bought from the market, agro-industrial by-products, and processed feed. The cpdm (%) ranged from 6.54$\pm$0.2 (*Eleusine indica*) to 23.08$\pm$0.3 (*Leucaena leucocephala*), NDF DM range from 28.42$\pm$0.3 (*Moringa oleifera*) to 67.16$\pm$0.2 (*Eleusine indica*), ADF DM 15.79$\pm$0.3 (maize gluten) to 45.56$\pm$0.3 (cowpea haulm).
The nutritional status of the available feed resources in the ecological area is high quality. The large expanse of fertile land can support viable investment in cattle production. Thus the relevance of bio-informatics to livestock production systems for desirable policy framework.

Keywords: Ecological zones, forage, GIS, GPS, production system, ruminant nutrition

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Bush fodder production on commercial farms in the Waterberg region, Namibia: challenges and potentials

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As a result of climate change, imminent desertification and accelerating bush encroachment, semi-arid rangelands are under increasing pressure. The Waterberg region in Namibia is predominantly farmed by commercial cattle farmers. Interviews from 2019 have shown that farmers were struggling with a severe drought in 2018 and 2019. One short-term coping strategy was to produce bush-based feed. The present study analysed challenges and potentials of the use of bush-fodder in that region. Semi-structured interviews were conducted with ten farmers, looking into their general farming business, rangeland management and their knowledge, experience and perception about the use of bush fodder. Additionally, feed samples were taken and analysed in a feed-quality laboratory. The analyses included the classical Weende fractions, van Soest fiber fractions and *in vitro* incubation in the Hohenheim gas tests. Based on the results, the samples were assigned an overall quality-score ranging from -5 (very poor) to 5 (very good). Most farmers (n=7) stated they only used bush-fodder during the drought, to cover the maintenance requirements of their livestock, and because there was no other feed available. The average quality-scores of pure bush samples, bush-based total mixed rations (TMR) and a mineral lick containing bush were -1.1 and 2 respectively. Correlation analysis indicated that poor quality of bush-feed lowers the willingness of farmers to use it in the future ($r^2 = -0.88$). Yet, a perceived good acceptance by the animals is positively correlated with the willingness of farmers to use it again in the future ($r^2 = 0.92$). The most frequently named barriers against future investments in bush-fodder preparation were monetary costs (n=9), labour costs (n=7) and (unknown) quality (n=6). Other constraints were "lack of necessity" and "unmatching price performance". Bush-fodder production may not have great potential as a permanent feed. But seemingly, its use was a good short-term risk mitigation strategy. When harvested shortly after the wet season and produced on stock it can serve as a sustainable feed for following years. Besides high investment costs, some farmers are continuing to use bush feed as they perceive it as a win-win situation due to the necessity to remove bushes on parts of their farm anyway.

Keywords: Bush encroashment, bush fodder, cattle, feed quality

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Carcass yield of giant african snails of the species *Archachatina marginata* bred in captivity (Swainson 1821)

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The carcass yield of giant African snails, *Archachatina marginata*, subjected to a restrictive diet for 70 days and then refed for 70 days, was evaluated. The objective was to determine the ability of the species to compensate for growth retardation. The study took place at the application farm of the Faculty of Agronomy of the Parakou's University between August 15, 2019 and January 22, 2020. A total of 90 snails, with an average live weight of 52.48 $\pm$ 9.03 g, were randomly divided into three batches of 30 subjects in semi-buried enclosures made of cement block and fine-mesh wire netting. Three mealy rations containing 20.26 %, 17.18 % and 14.43 % crude protein and 2976 kcal, 2540 kcal and 2089 kcal of metabolisable energy per kg of dry matter were distributed *ad libitum* to batches I (control), II and III respectively. At the end of each feeding period, 8 snails from each batch were randomly selected and slaughtered. The feed consumption indices as well as the carcass yields were respectively 1.94 $\pm$ 0.51; 3.44 $\pm$ 1.07 and 4.31 $\pm$ 1.03 ($p < 0.05$) as well as 38.70 $\pm$ 3.12%; 30.35 $\pm$ 2.03 % and 28.30 $\pm$ 1.26 % ($p < 0.05$) respectively for batches I (control), II and III at the end of the feed restriction period. After the refeeding period where all the batches of snails were fed at the same level as the control batch, these values were respectively 2.55 $\pm$ 0.35; 1.65 $\pm$ 0.14 and 1.60 $\pm$ 0.14 ($p < 0.05$) as well as 40.44 $\pm$ 4.00%; 37.48 $\pm$ 2.56 % and 36.55 $\pm$ 1.75 % ($p < 0.05$) respectively for batches I, II and III. It appears from this study that temporary feed restriction followed by refeeding significantly improved feed efficiency in *Archachatina marginata*. The carcass yield, despite a remarkable increase, could not be fully compensated.

Keywords: *Archachatina marginata*, carcass yield, feed efficiency, feed restriction

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Healthy animals as high quality food resource

Hygiene practices and safety of milk supplied by smallholder farmers in agroecological zones in Kenya

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Smallholder farmers dominate the Kenyan dairy sector producing 95 % of the total milk. These smallholder dairy farmers employ agroecological farming depending on the various climactic zones in which they are located. However, several concerns have been raised on the quality and safety of the milk they produce. This study assessed the hygienic practices and microbial safety of milk supplied by smallholder farmers to processors in three agroecological zones: Highlands, Upper Highlands, and Lower Highlands in Kenya. Interviews and direct observations were carried out to assess hygiene and handling practices by farmers and a total of 92 milk samples were collected along four collection channels: direct suppliers, traders, cooperatives with coolers and cooperatives without coolers. Microbial analysis was done following standard procedures and data analysed using GenStat and SPSS. This study revealed that farmers did not employ good hygienic practices in their routine dairy management. They used plastic containers for milking and milk storage (34.2 %); they did not clean sheds (47.9 %) and did not set aside cows that suffered from mastitis (83.6 %), resulting in poor microbial quality of raw milk along the collection channels. The study showed that microbial contamination began at the production level and increased during handling at the cooperatives and during transportation in the hot tropical temperatures without cooling. The highest mean total viable counts (8.72 log10 cfu ml^{-1}) were recorded in the highlands while the upper highlands had the highest mean *E. coli* counts (4.97 log10 cfu ml^{-1}) and the lower highlands recorded the highest mean counts of 5.13 and 5.78 log10 cfu ml^{-1} for *Staphylococcus aureus* and Listeria monocytogenes respectively. Based on all above-mentioned parameters, the microbial load in most samples from all three agroecological zones exceeded the set Kenyan standards. Farmer training, improving road infrastructure, use of instant coolers at cooperatives, and quality-based payment systems are recommended as measures to curb microbial growth and improve quality of milk to avoid wastage through contamination.

Keywords: Agroecological zones, dairy farmers, hygiene, Kenya

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What factors influence farmers' willingness to pay for East Coast fever vaccination in Tanzania?

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East Coast fever (ECF) is caused by *Theileria parva*, a parasite transmitted by ticks (*Rhipicephalus appendiculatus*). This parasite causes severe losses in cattle stocks and thus economic losses in Eastern Africa. A vaccine is available to mitigate ECF-related cattle losses. The immunisation procedure relies on ITM, the Infection-and-Treatment Method of vaccination. This study aimed to gain a better understanding of the vaccine adoption by analysing decisive attributes of farmers and their animal healthcare providers in Tanzania. Data was recorded by ILRI, the International Livestock Research Institute, through two questionnaires specifically tailored for farmers and healthcare providers, respectively. The farmer sample comprised 994 records; out of these, 543 farmers were using the ITM vaccine. Farmers adopting and paying for the vaccine (adopters) were compared to farmers not using it (non-adopters), in terms of area (ha) of cultivated land, crop sales revenues per hectare cultivated, cattle herd size (in tropical livestock units, TLU), share of milk sold, livestock product sales revenues per TLU, and education level of the farmer. Additionally, three variables pertaining to the individual farmer's healthcare provider were assessed, namely possibility to pay for ITM at a later point in time (yes or no), means of transport used for farm visits (motorbike or car), and travel distance (km) covered by the healthcare provider. Results show that among illiterate farmers (n=83), 43 % were having their cattle vaccinated with ITM. The picture reversed for farmers with an education level up to primary school (n=695), of whom 52 % had adopted the vaccination; lastly, among farmers with secondary and post-secondary education (n=216), the share of adopters was 68 %. Adoption of the ITM vaccination was associated with higher annual revenues from livestock product sales:
vaccine-adopting farmers (n=543) generated 1766 thousand Tanzanian shilling per TLU and non-adopters (n=451) achieved 1307 thousand Tanzanian shilling per TLU. These results suggest that ITM usage depends on education as well as on the direct economic benefits related to its use, and possibly also on the financial means available to pay for it. Yet, disentangling education from generated revenues and availability of additional financial means warrants further analysis which is currently ongoing.

Keywords: Adoption, East Coast fever, education, infection and treatment method, Muguga cocktail, revenues

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Effects of wet and dry ageing on the physiochemical and sensory quality of common eland meat (*Taurotragus oryx*)

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With a growing population and an increase in demand for meat, alternative protein sources including meat from game species, such as the African antelope, can supplement this need. Meat derived from local game meat species are in line with agroecological practices, as their production is extensive, the antelopes provide services to their local environment, are a source of nutrition, and strengthen the diversity and resilience of local food systems in East and Southern Africa. However, consumers do demand products of high quality that meet their nutritional and sensorial needs. Little is known about the common eland regarding optimising their meat quality for commercial consumption. In this study, the effects of wet and dry ageing on the physiochemical and sensory quality of common eland meat were investigated. The physical quality changes (pH, cooking loss, weep loss, CIE Lab colour, and WBSF) and the sensorial attributes of wet aged (vacuum-packaged) and dry aged longissimus lumborum (LL) muscles were evaluated for female (n = 6) common eland, during a 14-day post-mortem ageing period at 4°C. The dry aged LL muscle reached a shear force of 57.6 N, while the wet aged LL muscle reached a shear force of 63.3 N. These values are typical for game meat, however, the meat would be considered as tough by the average consumer (> 49N). The weep loss of the dry aged muscles were higher than of the wet aged meat, but improved the flavour of aged eland meat by decreasing the abnormal aroma intensity and liver flavour compared to the wet aged LL muscle. The dry aged LL muscle scored higher in overall acceptability, even though the specific differences in tenderness between the two ageing techniques were not noted by the sensory panel. Thus, while ageing did improve the tenderness of the LL muscle, dry ageing showed favourable flavour development.

Keywords: Game meat, longissimus lumborum, meat quality, *Taurotragus oryx*, tenderness

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Effect of *Ocimum gratissimum* on egg quality of laying hens

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Eggs are a source of good quality protein for human consumption. It is considered a complete protein because it contains all the essential amino acids required for human growth and development. *Ocimum gratissimum* (*lyn*) is a medicinal plant with biological and physiological properties useful to both humans and animals. Egg quality such as shell thickness, yolk colour is of benefit to both farmers and consumers of eggs. This study was designed to determine the effect of *O. gratissimum* on egg quality of eggs from laying hens when consumed as an aqueous extract or as a component of feed. A total of sixty bovan brown laying hens (22 weeks old) were randomly distributed to three treatment groups having five replicates and four birds per replicate. Birds in treatment 1 (T1) served as the control group while birds in treatment 2 (T2) were administered 1 ml bird^{-1} freshly prepared *O. gratissimum* extract twice a week. Birds in treatment 3 (T3) were fed a standard commercial layer's diet supplemented with *O. gratissimum* chaff at an inclusion level of 50 g kg^{-1} DM of complete feed. A commercial layer's diet was given to all the birds in the respective treatment groups. The experiment was designed as a completely randomised design and lasted eight weeks. Eggs were collected from each replicate on a daily basis; however, egg quality analysis was randomly carried out on day 56 of the experiment. Egg quality determined were; egg width, shell thickness, albumen weight, albumen height, yolk weight, yolk height and yolk colour. Each variable was measured using appropriate method. Data collected was subjected to a one-way analysis of variance and significant means separated using Duncan's multiple range test. The results showed that there were numerical differences in all the variables measured except yolk colour, however, these differences were not statistical different ($p < 0.05$). Yolk colour was significantly improved ($p < 0.05$) by administering 1 ml bird^{-1} of aqueous *O. gratissimum* extract. A value of 8.70 was obtained in (T1), 10.28 (T2) and 6.87 (T3); respectively. Administrating 1 ml bird^{-1} of *O. gratissimum* extract improved yolk colour of laying hens.

Keywords: Egg quality, laying hens, *Ocimum gratissimum*, yolk colour

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Assessment of natural (KLH) antibodies and specific (Newcastle disease) antibodies in local chicken of Kenya

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Natural and specific antibodies are important in combating and controlling diseases. The antibody traits, as part of the immune function, provide an indication of an individual's health status and are used as indicator traits of disease resistance. Selective breeding to improve any trait, including antibody traits, requires identification of sources of variation. This study aimed at determining non-genetic factors related to biological and environmental effects that confer variation in natural and specific antibodies in local chicken of Kenya. In this study, natural antibodies binding to Keyhole Limpet Hemocyanin (KLH-NAbs) and specific antibodies binding to Newcastle disease virus (NDV-IgG) were used as measures of immune traits. The population in the study constituted of indigenous chicken and synthetic chicken populations that have been subjected to selection to develop meat and egg lines over five generations. A total of 1540 chicken of different ages ranging from 12 to 56 weeks were sampled. Titers of KLH-NAbs isotypes (KLH-IgM, KLH-IgG and KLH-IgA) and NDV-IgG were measured by indirect enzyme-linked immunosorbent assay. A general linear model was fitted to determine the effect of sex, population, generation, phylogenetic cluster, line, genotype, hatch group, plate and age on the antibody traits. Overall mean ($\pm$ standard error) concentration levels for KLH-IgM, KLH-IgG, KLH-IgA and NDV-IgG were 10.33 ± 0.04, 9.08 ± 0.02, 6.00 ± 0.02 and 10.12 ± 0.03, respectively. Sex, generation and age (linear covariate) influenced ($p < 0.05$) variation across all the antibody traits. Population and genotype effects ($p < 0.05$) were evident in all antibody traits, apart from KLH-IgA. Hatch group had an effect ($p < 0.05$) on KLH-IgA and NDV-IgG. Interaction between generation and line was significant ($p < 0.05$) in KLH-IgM and NDV-IgG while nesting cluster within population influenced ($p < 0.05$) all antibody traits, apart from KLH-IgA. Results from this study indicate presence of biological and environmental effects on natural and specific antibodies. These factors should be accounted for to reduce bias and improve accuracy when evaluating the antibody traits. Adjusting for these factors is further expected to improve accuracies of genetic evaluations of the antibody traits.

Keywords: Chicken, natural antibodies, non-genetic factors, specific antibodies

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Capacity building and education for animal health professionals through training materials to improve animal welfare

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The veterinary profession, including veterinarians and veterinary paraprofessionals (assistants, veterinary technicians), plays a leading role in animal welfare. OIE describes their duty in recognising and managing animal welfare (AW) issues, as well as advising animal keepers, owners, care-takers and policy makers in AW related issues.
Unfortunately, the topic has often been neglected in veterinary education. According to a survey performed by Welttierschutzstiftung (WTS) in 2014 among veterinary training institutions and NGOs, 58 % of respondents expressed a lack of AW education in veterinary curricula and 44 % said especially veterinarians lacked AW knowledge.
WTS aims to address this issue and supports the integration of animal welfare in animal health related courses and CPD programmes by offering free training materials with focus on applied animal welfare. The foundation works in close cooperation with educational institutions in the animal health sector, veterinary associations, local government departments and NGOs to accomplish the mission: to increase the animal welfare awareness among professionals and thus in their communities and among relevant stakeholders. In the direct scope of the WTS VETS UNITED projects the training materials are currently used at 11 academic institutions and in 2 CPD programmes in 7 African countries.
This year, a small team of professionals from Africa, South America and Europe, in collaboration with peer reviewers from countries world regions are updating the training materials. The new version will reflect the latest developments in animal welfare science and include new topics on emerging challenges like antimicrobials resistance and One Welfare, in order to make teaching animal welfare easy, effective and fun.

Keywords: Animal health professionals, animal welfare, capacity building, training materials

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Growth control of cyanobacteria strain LmTK01 using specific bacteria in laboratory (*in vitro*)

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In recent years, algal blooms are worldwide problems in water resources, including in aquaculture ponds. Blue-green algae are one of the most common group that bloom in the water and affect the environmental safety, organism and human health. Cyanobacteria strain LmTK01 is a blue-green algae that has been found to bloom in shrimp ponds in Songkhla province, Thailand. Which is a problem in shrimp farming. The objective of this study was to use bacteria from aquaculture water to inhibit cyanobacteria strain LmTK01 growth. Morphology and identification of algicidal bacteria were studied based on phenotypic characteristics and 16S ribosomal RNA (rRNA) gene sequence. Cell density and algicidal modes of strongest algicidal bacteria on LmTK01 growth were measured by absorbance at 680 nm. A total of 53 strains of bacteria were isolated and screened which found that strain BP5 showed the highest algicidal activity at 99.94 % on day 7 of the experiment. Results of morphology study of strain BP5 showed that strain BP5 was a gram-positive, rod-shaped, orange cream colony and endospore formation was observed. 16s rRNA gene revealed that strain BP5 was a member of the genus *Fictibacilus*. The optimal cell density of strain BP5 was 10^7–10^8 CFU mL^{-1}, which algicidal activity was greater than 50 % significantly different from 10^5–10^6 CFU mL^{-1} ($P < 0.05$). In addition, when strain BP5 was inoculated with other algae (*Chaetoceros* sp., *Skeletonema* sp., *Chlorella* sp., *Scenedesmus* sp. and *Spirulina* sp.). It was found the most specific effect significantly on LmTK01. Moreover, Algicidal modes of the bacterial culture and cell-free filtrate showed that algal cells were clearly destroyed and algicidal modes of strain BP5 were higher than control and bacteria cell groups. The results indicated that the algicidal bacteria strain BP5 specifically and effectively controlled the cyanobacteria strain LmTK01 bloom.

Keywords: Algicidal bacteria, bacteria cell, bacterial culture, blue-green algae, cell-free filtrate, cyanobacteria strain LmTK01

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Digital innovation for enhancing dairy productivity

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Livestock sector is very dynamic in developing countries as there is high demand for animal products due to rapid urbanisation, population growth and income growth. This poses a wonderful opportunity for small and marginal farmers to get benefit as they own major proportion of livestock in developing countries. Despite India being a number one in milk production in the world with milk production of 209 Mil tonnes, the dairy productivity found exceptionally low with 1700 kilograms per lactation compared to more than ten thousand kilograms per lactation in USA and Israel. India achieved remarkable milk production through greater number of dairy animals (190 million cattle) than improving dairy productivity. Increased milk production is highly associated with absolute greenhouse gas emission unless efficiency of production increased, and number of dairy animals decreased. There is need to understand the prevailing issues of low productivity in dairy animals which can support to build strategies for improving efficiency in dairy production. The proposed study is the first step to identify the core issue of unproductive dairy animals in rural villages. Data collected from 5504 dairy animals of sixty villages in Tamilnadu, southern state of India. Data collections were done on reproduction status of animals, lactation stage of animals, prevalence of diseases and availability of feed and fodder resources. The results indicated that only 38 % of animals were in milking and 24 % of animals were in pregnant stage among the adult cows. This indirectly indicates the issue of long intercalving period and low fertility rates in dairy animals. Approximately 18 % of animals found with repeat breeder issue, not conceived even after 4 inseminations. Precise livestock farming using digital innovations are promising to fill the gap in data and information and to develop evidence-based interventions for enhancing dairy productivity and decrease greenhouse gas emission.

Keywords: Dairy productivity, digital innovation, smart dairy

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Potential impacts of urbanisation processes on dairy cattle health in greater Bengaluru, India

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In the Greater Bengaluru metropolitan area, feeding of dairy cattle still depends to a considerable extent on vegetation available on public land such as roadsides, lakeshores and designated construction areas. Due to rapid urbanisation, these lands are declining, forcing animals and farmers to cover longer distances to reach alternative forage sites. This may reduce feed supply, higher risk of accidents and solar radiation while walking along roadsides and heat back-radiated from the tarmac. To learn more about the impact of accelerated urbanisation on the well-being of dairy cattle in Bengaluru, 151 farmers, located in different parts of the megacity, were individually interviewed during January to March 2020. Questions addressed feed sources and feeding practices, daily walked distances, drinking water supply at home, housing conditions and medical care. The results indicated that 58 % of the farmers kept crossbreds of exotic *Bos taurus* dairy breeds with local *Bos indicus* cattle, and 42 % kept crossbreds of dairy zebu breeds with local cattle. More than half of the farmers (63 %) walked their cattle to grazing areas each day, and 46 % collected forages on public grounds, with 9 % combining both practices. In addition, cows were supplemented with concentrate (99 % of farmers). However, only 60 % of the farmers thought that their animals were supplied with sufficient amounts of feed, and only 20 % acknowledged sufficient access to drinking water. While most farmers (94 %) kept their animals in confined sheds at nighttime, only 72 % considered shed space as adequate and 10 % complained about high ambient temperatures inside the shed. In consequence, only 60 % of the interviewed farmers judged that their cows were in good health, although 95 % of the interviewees were regularly vaccinating them against foot-and-mouth disease. Results of a logit model showed that exotic cattle genetics (Holstein Friesian and Jersy crossbreds) and amount of feed affected cattle well-being in a positive way ($p < 0.05$), while the grazing or collection of lakeshore fodder ($p < 0.01$) and low quantity of drinking water ($p < 0.05$) had an adverse impact on cattle well-being. Farmers and farm advisors need to address these challenges of urbanisation for health and productivity of dairy cattle in Greater Bengaluru.

Keywords: Cattle health, lake fodder, logit model, pooled resources, survey

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Insects as food and feed source in the tropics: opportunities and constraints of forage-based insect diets

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Farmed insects can provide an alternative protein source for humans, livestock, and fish, while supporting adaptation to climate change, generating income for smallholder farmers, and reducing the negative impacts of conventional food production, especially in the tropics. However, the quantity, nutritional quality, and safety of insects greatly relies on their feed intake. Tropical forages (grasses and legumes) can provide a valuable and yet untapped source of feed for several farmed insect species. In this literature review, we provide a perspective on how tropical forages can support edible insect production. We also highlight the potential of tropical forage-based diets over those using organic agricultural or urban by-product substrates, due to their versatility, low cost, and lower risk of microbial and chemical hazards. Our results show that insects are a viable option for supplying the growing demand for protein in the tropics, especially given the need to adapt to and mitigate climate change. The advantages of insect farming in the tropics include a greater biodiversity, production throughout the year under stable environmental conditions, and the contribution to at least 8 Sustainable Development Goals. This has led to the development of an emerging industry, e.g., through initiatives based on black soldier fly production for fisheries in Kenya and Colombia. Organic residues and substrates, commonly used for this purpose, may, however, represent a hazard for both fishery and human health. We thus propose a new approach for insect-based value chains by integrating tropical forage-based diets in edible insect production systems, given the yet untapped forage diversity in international gene banks and on farms. Compared to commercial diets, tropical forages are a low-cost feed source for insects, with high dietary versatility, that provide opportunities for the transition to sustainable, circular economies. The main bottlenecks are the lack of specific regulations, the dependence on few species for large-scale industrial insect production, and food safety. Our results will serve interested stakeholders in identifying urgent issues at the research, ethical, marketing, and policy levels that can prevent the emergence of new, insect-based value chains and business models, and the nutritional, economic, and environmental benefits they promise.

Keywords: Business models, edible insects, entomophagy policies, food security, sustainable development

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Population dynamics and fisheries management of the round sardinella, *Sardinella aurita* in GSA 26, Egypt

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Fisheries sector is playing a significant role in the national economy, human development and welfare, such as in terms of providing employment, production and trade. Fisheries resources in Egypt are providing a cheap animal protein and contribute greatly in the food security of the country. The round sardinella, *Sardinella aurita*, is one of the most important fish species in the Egyptian sector of the Mediterranean Sea contributing up to 33 % of the total fish production from Egyptian Mediterranean. Sardine constitutes the major component of the purse-seine catch in the Egyptian Mediterranean. Sardine catch is composed mainly of *Sardinella aurita, S. maderensis, Sardina pilchardus* and *Dussumieria acuta* from which the *S. aurita* is the most abundant species. The population dynamics and assessing the sardine stock were undertaken based on monthly samples collected between January 2019 and January 2021 from the fishing harbor at Port Said city. Age and growth studies based on sagittal otoliths revealed that this species has a maximum lifespan of four years and the age group I was the most frequent one in the catch where it constitutes about 55 %. Growth parameters of the von Bertalanffy growth model, estimates of total, natural and fishing mortality were estimated. Exploitation ratio was more than the optimum one as well as the length at first capture was smaller than the length at first sexual maturity indicating that this stock is suffering from the high level of exploitation. The high values of fishing mortality and exploitation ratio indicated that this species was harvested at a higher level than the optimum fishing mortality and this fishing pressure should be reduced to obtain maximum sustainable yield (MSY). The yield per recruit analysis suggested that the *S. aurita* stock in the Port Said region needs regulatory measurements to achieve its sustainable development. Also the fishing gears used need to be re-evaluateD and to be improved to catch larger fish.

Keywords: Egypt, management, population parameters, round sardine, stock assessment

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Sustainable production of yellow mealworm for protein food using low-value agricultural by-products

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With continued population growth and increasing consumer demand for protein, the edible insect is considered sustainable protein food with low environmental impacts. Advantages of edible insects include a high feed-conversion efficiency of insects and the rearing on organic material, adding value to waste and decreasing environmental contamination. Compared to cattle, pigs, and poultry raising, insects emit relatively few greenhouse gases and little ammonia and require significantly less farm area and water. Some insects can convert agricultural waste or by-products into high-quality protein. The aim of this research is to assess the growth of yellow mealworm larvae (*Tenebrio molitor* L.) reared with 4 different diets based on vegetables and brans. The diets were rice bran, rice bran mixed with Chinese cabbage, wheat bran, and wheat bran mixed with Chinese cabbage. The yellow mealworm larvae grew healthily and had a life cycle of around 5–5.5 months. The full-grown larva fed on rice bran mixed with Chinese cabbage showed a significantly shorter larva stage than those of the larvae fed on rice bran, wheat bran mixed with Chinese cabbage, and wheat bran (12.53 %, 16.71 %, and 17.76 % respectively). The survival rate of yellow mealworm larvae was non-significantly different (ranging from 53–76 %), and the full-grown larva fed on rice bran mixed with Chinese cabbage and rice bran (71 g), and wheat bran (80 g) had similar yield per rearing tray but they had a lower yield than wheat bran mixed with Chinese cabbage (131 g). The estimated production costs of the fresh yellow mealworm larvae range from 4,070 to 6,742 € per ton.

Keywords: Rice bran, sustainable protein food, *Tenebrio molitor* L., wheat bran, yellow mealworm

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Nutritive value of meat from Philippine white mallard (*Anas boschas* L.) and Pekin ducks (*Anas platyrynchos* L.)

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Philippine white mallard ducks were compared with Pekin ducks in terms of their potential for meat production. A total of 50 ducklings were randomly assigned to 5 pens per treatment after 1 month of brooding. Each pen containing five ducks was considered as a replicate. Ducks were raised until 12 weeks of age and slaughtered at the end of the growing period. Skin and lean samples from the breast and the legs of each breed were taken and analysed for amino acid, fatty acid, and cholesterol contents. Data were subjected to the independent sample t-test. Essential amino acid profiles of both duck breeds have no significant differences except for leucine and isoleucine, for which higher levels were obtained in Pekin duck meat. The total non-essential amino acid content of Pekin duck meat was also significantly higher than the meat from Philippine white mallard, although the individual amino acid did not differ between breeds. Fatty acid composition from the meat of both breeds of duck did not show any significant differences. However, Philippine white mallard duck meat was noted to have significantly higher cholesterol content in both skin and lean compared with Pekin ducks. Results showed that the nutrient content of meat from both duck breeds was comparable. From a health point of view, Pekin duck meat may have an advantage over Philippine white mallard due to its lower cholesterol content.

Keywords: Water birds

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Acidifier reduce African swine fever virus in commercial pig feed under tropical conditions

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African Swine Fever virus (ASFv) causes lethal disease in pigs with mortality up to 100 %. Feed or feed materials can serve as potential vectors for the introduction and transmission of AFSv. Recent data show that organic acids, e.g. formic acid and medium-chain fatty acids, may exert an anti-viral impact against ASFv, albeit with some limitations (high dosages, *in-vitro* data). However, data on a combined approach of organic acids and medium chain fatty acids are scarce. This study investigates the impact of an agglomerate of sodium diformate and medium chain fatty acids (MCFA) on its ability to reduce the activity of ASFv in feed under tropical conditions in northern Vietnam.

The experiment was designed to evaluate the viability of ASFv (p72, genotype II) over time (0, 1, 3 and 7 days post-inoculation) in commercial swine feed containing either 0 % or 0.3 % of an agglomerate of sodium diformate and MCFA (Formi Alpha, ADDCON). Feed bags were incubated with a viral concentration of 10^8 HAD_{50}/mL. After the appropriate post-inoculation incubation period, surviving virus was eluted from the samples using RPMI 1640 medium with 5 % fetal bovine serum. Virus titers (HAD_{50}/mL) were calculated by the Karber method. The quantity of ASFv was determined by real-time PCR to measure Ct-value. A significance level of 0.05 was used in all tests.

The ASFv titration assay on cell cultures showed that the feed acidifier had a significant reduction activity against ASFv throughout the whole period, beginning after a few hours. The 0.3 % inclusion of the additive was able to inhibit the virus within less than one hour significantly, from 4.72 to 4.10 Log_{10} HAD_{50}. From day 1 onwards, the reduction was highly significant ($p < 0.001$). On day 7, the ASFv was inhibited completely.

Addition of low dosages of Formi Alpha caused a highly significant reduction of the viral load in commercial swine feed – achieving complete inhibition of the virus after 7 days and can be consequently an economical and sustainable approach to curb disease transmission while reducing infection probability for pigs exposed to virus-contaminated feed.

Keywords: Acidifier, African Swine Fever, feed, medium chain fatty acids, sodium diformate

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Forty-five years of animal health research at the International Livestock Research Institute, Kenya

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Livestock have been called the engine of development in low- and middle-income countries (LMICs). They support the livelihoods of the poorest and offer a pathway out of poverty; livestock is a sunrise sector, rapidly growing in response to demand and hence offering an opportunity for economic growth along with nutritional improvement.

2021 saw the launch of a book on the impacts of 45 years of research at the International Livestock Research Institute (ILRI). The book represented four years of effort from over 70 authors. Among the main findings were that the international community invested nearly US$12 billion in global livestock research from 1975 to 2018: most was financed in ILRI and most spent in sub-Saharan Africa and this had substantial and objectively verifiable impact.

Research covered all aspects of livestock, yet it is interesting to note that 9 of the 18 chapters are relevant to One Health. Among the main findings are:

• Veterinary epidemiological and economic impact sciences increased understanding of infection dynamics and generated a wealth of methodologies and approaches that have since been applied in every corner of the world.

• One Health approaches estimated the burden and risk factors for neglected as well as emerging zoonoses, identified their drivers and developed strategies for reducing those risks

• Field research on trypanosomiasis determined that rational use of curative and preventive trypanocidal drugs is the most sustainable and scalable control

• Research on food safety elevated the importance of informal markets where most of the poor buy and sell, introduced risk assessment to LMIC, conducted dozens of burden studies and developed new approaches to managing food safety.

The book captures ILRI benefits to research, capacity development and end users. It marshals substantial evidence to show that livestock research improved food and nutrition security, prosperity, and natural resource management in LMICs.

Keywords: Animal health, research

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Assessment of performance and egg quality of laying hens fed black pepper and red pepper additives

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With the increasing demand for poultry products over the world, poultry farmers want to improve the productivity of their flocks. This challenge has necessitated poultry nutritionists to offer certain nutritional strategies for improved productivity. Feed additives have been recommended as one of such strategic options and plant materials known as phytogenics are being extensively investigated. The objective of the study, therefore, was to assess the performance and egg quality of laying hens fed black pepper and red pepper additives. A total of 210 laying hens at 24 weeks of age were allotted seven dietary treatments in a completely randomised design. Each treatment had 30 birds each, replicated three times to give 10 birds per replicate. The formulated diets included: a control diet with no additives; Treatments 2 and 3 had 1 % and 1.5 % black pepper powder; Treatments 4 and 5 had 1 % and 1.5 % red pepper powder; Treatment 6 had a mixture of 0.5 % each of black pepper and red pepper, while treatment 7 had a mixture of 0.75 % each of black pepper and red pepper. All data collected were subjected to a one-way analysis of variance, using the general linear model procedure of SAS (2012). From the results obtained, the hen day percentage was significantly highest in hens fed the diet with 1 % red pepper (83.40 %) and the least from hens in the control (65.56 %). The control treatment also recorded significantly least performances in egg mass (48.76 g per bird and day) and feed conversion ratios(2.58 and 2.30). Shell thickness was least (0.43mm) in hens fed the diet with 1.5 % red pepper, while the thickest shell measurement (0.50mm) was recorded in Treatment 6. The highest Haugh unit of 103.77 was obtained from Treatment 4, while the least value of 96.66 was obtained from the control. Yolk colour was significantly improved in the treated groups as against what was obtained from the control. It can be concluded that black pepper and red pepper, having improved the measured parameters in comparison to the control group, hold great potential as dietary additives that can help improve the performance and egg quality of commercial laying hens.

Keywords: Black pepper, egg quality, feed additives, laying hens, performance, red pepper

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(Agro)forestry

Agroforestry systems sustainability

Oral Presentations

Posters

Economic risk analysis of Gliricidia-Maize system in selected dryland areas of Dodoma region in Tanzania

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Using data from farm budget and from simulations using the Gliricidia and maize models of the Next Generation version of the Agriculture Production System sIMulator (APSIM), this paper evaluates the economic viability and risk of Gliricidia-Maize and sole maize systems. A Monte Carlo simulation model was used to simulate maize yields and net returns of the Gliricidia-Maize and sole maize systems. Results show that the probability of attaining the potential grain yields of maize (4.5 a^{-1}) is higher in the Gliricidia-Maize than in the sole maize system (0.34 versus 0.03). In contrast, risks to net returns is higher in the sole maize (CV=44.93 %) than in the Gliricidia-Maize system (CV=37.95 %). The probability of exceeding the income poverty line of around Tsh 600,000 per adult equivalent per year is higher in the Gliricidia-Maize than in the sole maize system. Stochastic efficiency analysis results show that the Gliricidia-Maize system is more preferred than the sole maize system at lower (0) and upper (4) Risk Aversion Coefficients (RAC). The certainty equivalent values of grain yields of maize in the Gliricidia-Maize system are 17.5 % and 5.9 % higher at lower and upper RAC, respectively, under the negative exponential utility function. Based on these results, it is plausible to argue that the Gliricidia-Maize system is more economically viable than the sole maize system thus risk-neutral and extremely risk-averse smallholder farmers would prefer this system. Scaling up of Gliricidia-Maize agroforestry intercropping technology is therefore expected to lead to a reduction of food and income poverty in selected dryland agro-ecologies of the Dodoma region in Tanzania.

Keywords: APSIM, dryland areas, Monte Carlo simulation, risk

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Suitability of methods for assessing the sustainability of agroecological transition-dynamics in crop-livestock-tree farming systems

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Many tools have been developed to assess the sustainability of agricultural production. However, the majority of the existing methods are limited to investigating strengths and weaknesses of already established farming systems. As such, these methods may not be suitable for assessing the sustainability of dynamics in the farming systems when they are transiting towards being either organic or agroecological farming. Studies in this regard are sparse. To address this limitation, we conducted a comparative analysis of six sustainability assessment tools. These tools were IDEA (Indicateurs de Durabilité des Exploitations Agricoles), MOTIFS (Monitoring tool for integrated farm sustainability), SAFA (Tool for Sustainability Assessment of Food and Agriculture Systems), TAPE (Tool for agroecology performance evaluation), ESSIMAGE (Tool for the assessment of the agroecological performance of agricultural production systems), and a framework developed by GTAE organisation to evaluate effects and conditions of agroecology. The tools were compared through two main criteria: scientific soundness and user-friendliness, using a scoring system with the range from 0 to 3 for sub-criteria, adapted and adjusted from Talukder & Blay-Palmer, (2017). Performance criteria in economic, environmental, and social dimensions from different tools were compared for similarities, differences, and alignment with principles of the agroecological farming. Further, the tools were tested on their ability to deal with transition-dynamics in crop-livestock-tree farming systems towards safe food systems. Results showed that the MOTIFS and SAFA scored the highest for scientific soundness and user-friendliness in the sustainability assessment, followed by IDEA and TAPE. TAPE, SAFA, MOTIFS were found to be more sensitive in assessing the multi-functional performance of agroecological farming systems and the transition to agroecology. In conclusion, TAPE, SAFA, MOTIFS tools are more suitable than other methods to investigate the sustainability of agroecological transition-dynamics in crop-livestock-tree farming systems.

Keywords: Sustainability assessment methods

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Lessons from the entanglement of adaptive capacity and response in complex agricultural systems: Evidence from a coffee landscape in Vietnam

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Capacities to adapt to a changing climate are differentiated by ecological, social and individual factors, varying over time and space. Adaptive capacity can be conceptualised as the ameliorative component of vulnerability and as the enabling precursor to prepare, respond, adjust, and cope under stress or change. Assessment of adaptive capacity (and vulnerability) are often critiqued for "promoting a static understanding of human-environment interactions" and there are numerous calls to integrate temporal and spatial scale dynamics into their assessment. We look to derive temporally and spatially dynamic indicators to assess adaptive capacity in a complex agricultural system (as contributing within a vulnerability framework). Within this framework, we attempt to better formulate the [spatio-temporal] pathways between adaptive capacity and adaptive response, as illustrated by the uptake of intercropping in coffee systems the Central Highlands of Vietnam.
The distinction between adaptive capacity and adaptive response is not as clear-cut in practice. For example, adaptive capacity may facilitate the implementation of intercropping and cyclically, intercropping may increase adaptive capacity. This fuzzy line is reflected in concepts such as generic and specific capacity, respectively: demographic and socioeconomic characteristics of a population, and actions taken to confront risk. Specific capacity, such as labour or crop diversification, change in varieties planted or irrigation management would also all fall under the category of adaptive response. With a temporal adaptive capacity indicator, we can capture the implementation of adaptive measures, such as intercropping, and their ensuing contribution to adaptive capacity, while also maintaining the complexity of other generic and specific contributing factors and their evolution in time and space. We would present our (exploratory) characterisation and relative measurement of adaptive capacity in the Central Highlands coffee landscape, quantified using results from a household panel survey (2013, 2017), and preliminary results distinguishing the contributions of intercropping.

Keywords: Adaptive capacity, agroforestry, climate adaptation, coffee, intercropping, Vietnam

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Carbon sequestration in aboveground biomass within a diversity gradient of different cocoa agroforestry systems

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Quantifying carbon (C) sequestration rates is essential for carbon offsetting programs with cocoa agroforestry systems (AFS). However, they can vary substantially between AFS and depend on several factors, such as stand age, stand density, species diversity and management (organic and conventional). Few scientific long-term-studies exist on C sequestration rates within a diversity gradient of AFS. Within the framework of FiBL's long-term Farming Systems Comparison (SysCom), the objective of this study was to quantify above-ground C in different AFS at age 14. The AFS under investigation were under conventional (AFS CONV) and organic (AFS ORG) management as well as a highly diversified organic successional agroforestry system (SAFS) without external input use. Additionally, the aboveground C of two full-sun cocoa monocultures with organic (MONO ORG) and conventional (MONO CONV) management were measured to contrast C in full-sun cocoa systems and AFS. A total of 292 shade trees and 720 cocoa trees were measured non-destructively for aboveground C. Other measured C components were litter, dead wood banana/plantain biomass and herbaceous biomass. SAFS had the highest aboveground C storage with 48.91 t ha^{-1} followed by AFS ORG with 44.19 t ha^{-1}, and AFS CONV with 42.78 t ha^{-1}. C storage of MONO ORG and MONO CONV was 21.63 t ha^{-1} and 20.29 t ha^{-1} respectively. The long-term experiment shows that the different management regimes had an impact on total aboveground C. After 14 years, the highly diversified successional AFS without input use accumulated the highest aboveground C in comparison to conventional and organic AFS management treatments.

Note: Since this is an ongoing investigation not all results are available at this point in time.

Keywords: Agroforestry, cacao, carbon sequestration

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Taungya agroforestry programme in dryland of Sudan: Incentives, challenges and strategies for improvement

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Taungya agroforestry programme has been practised for a long time in different parts of Sudan as one of the strategies implemented by the Forest National Corporation to halt deforestation and forest degradation and as a mean of livelihood improvement for the communities surrounding the forest reserves. In the program, the Forest National Corporation allocated a predetermined area inside the reserved forests and provided the farmers with seedlings and technical assistance. Farmers are allowed to grow their subsistence and commercial crops between tree spacing at the early stage of tree establishment. In this study, both quantitative and qualitative methods were used with 200 Taungya farmers from nine villages around the Nabag Forest Reserve in South Kurdufan State, Sudan to discover the major incentives and challenges associated with Taungya programme in the study area. The study results revealed that the high productivity inside the forest, access to free land, and the highly fertile soil inside the forest were the main incentives for farmers to participate in the program. The study also indicates that the lack of extension services and supervision from Forest National Corporation, overgrazing and crop destruction, land size allocation, and crop species restrictions discourage farmers from participating. To overcome these challenges, the study suggested that: (i) the priority budget allocation be given to the extension services that could empower farmers and guarantee to transfer and deliver the extension services adequately; (ii) Taungya farmers could use the live fences to protect their farms and Forest National Corporation could facilitate this by allowing farmers to use the branches of failed trees during the migration season of pastoralists; and (iii) the Forest National Corporation should reconsider farmers' interest in having intercropping sorghum on their farms by revising tree spacing in the future.

Keywords: Challenges, incentives, Sudan, Taungya agroforestry

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From wasteland to oasis: Evidence of an agricultural development programme

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Current yield trends, especially in rain-fed farming areas, are not encouraging, and suggest a need for proactive policies. Little evidence exists, however, which can inform the design of policies to meet this goal.
We assess the impact and underlying causal relationships of an agricultural development programme and its potential to transform livelihoods and places of chronic poverty. The programme we scrutinize is the Wadi concept, an integrated farming system including water resource development, soil conservation, fruit- and forest trees and intercropping on one-acre (0.40 ha) of so-called "wasteland", which would not otherwise be used for rainfed crop growing.
The geographic rollout of the programme produced a natural experiment, giving raise to treatment and control groups. We follow a mixed methods approach, including a survey of 2,000 households, randomly sampled from 188,231 participants in 4 Indian states, covering geographically different areas. We compare households who participated in the programme to non-participants, and run a linear regression analysis, ceteris paribus comparing farmers that have established integrated farming systems respectively at different points in time over the period 1990–2017.
We find a clear and significant trend in improvement of socio-economic factors, including: food security, higher income, diversified income sources, positive life changes, higher life satisfaction and better future for children, as well as ecological benefits.
The effectiveness of the Wadi programme to provide sustainable development pathways implies benefits to be had from scaling it up. By rigorously assessing its potential to help farmers escape from chronic poverty and to build resilience, this study provides evidence in the science-policy dialogue of development programs.

Keywords: Agricultural development, chronic poverty, food security, integrated farming system, resilience, smallholder, sustainable intensification

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Mapping local knowledge systems about cacao agroforestry management: a comparison of two Colombian mountainous zones

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Agroforestry systems (AFS) have been recognised as an alternative to support the social-ecological transitions toward sustainability. These complex systems have mainly been promoted through a restricted set of technological packages. Thereby, they have not successfully spread beyond some farms or plots because they fail to consider the fine-scale variation of the particular local circumstances. Cacao agroforestry systems (CAFS) have been mainly promoted in tropical mountain social-ecological systems where detailed scientific data are usually lacking because of their intrinsic complexity. In this sense, the knowledge of smallholder cacao farmers to adapt their CAFS, which is based on their own experimentation under local circumstances, needs to be integrated to choose and promote appropriate management options.

The objective of this study is twofold: (1) to identify and represent local interdependent variables influencing CAFS management in two mountainous zones of Colombia, and (2) to explore a tool-based approach to integrating farmer's knowledge into AFS promotion. Participatory cognitive maps on CAFS management variables were developed with cacao smallholder farmers based on semi-structured interviews (n=18). Cognitive maps are graphical representations of complex systems, consisting of multiple variables and the causal relationships between them. Smallholder farmers' interviews were transcribed and their content analysed to refine the cognitive maps, which were then coded into adjacency matrices for further analysis with graph theory.

Results from the cognitive maps revealed an average of 28 ± 5 variables and 29 ± 5 links between management variables. All farmers interviewed recognised fertilisation, pruning, weed control, and pest management as the most important practices for successful cocoa production. Irrigation was added to these practices for one of the zones. Farmer use of ecological processes to optimise these main cacao practices considering their resource limitations was also evidenced, such as the identification of a particular cover crop to reduce weed control. As complex agriculture systems like CAFS remain a prominent solution to sustainability, this representation of farmer knowledge based on cognitive mapping could be useful for integrating local knowledge systems into agricultural extension services and future agroforestry-related projects.

Keywords: Agricultural extension services, cognitive mapping, complex systems, local knowledge systems, sustainable agriculture

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Building the evidence base for gender responsive circular economy innovations for food and energy security of refugee and host communities in East Africa

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At Tropentag 2020, an international consortium reported on the development and implementation of a gender responsive circular economy concept for both refugee and host communities in six refugee settlements in Ethiopia, Kenya and Uganda. In this paper, the same international consortium returns to present the progress made and the early stages in the building of an evidence base for gender responsive circular economy solutions for refugee settlements in East Africa. While the technical interventions – home gardens, agroforestry, fuel briquettes and improved stoves – are now in operation, with early indicators showing positive impacts from the home gardens, the social and environmental challengers at the macro scale are increasing across the region. In just the last two years, the forcible displacement crisis in East Africa has further escalated, pushing the number of refugees up from 3.2 million to 5 million, with the recent conflict in Ethiopia adding substantially to these numbers. For example, in Kenya, Ethiopia and Uganda the displacement figures now stand respectively as 0.5 million, 5.1 million and 1.5 million people. These rapid changes are only accelerating the competition over resources such as firewood, fertile land and water and increasing this risk of social tension between refugees and their surrounding host communities. In response to these challenges, using local partners and a participatory approach, a training manual in home garden, agroforestry and energy technologies has been developed and used for the 'training of trainers' and the subsequent delivery of training to over 1,360 beneficiaries from both host and refugee communities. This has included the implementation of over 700 home gardens, with fruit and multipurpose trees also planted in each garden. In this paper, the progress and challenges from the project are discussed. The early evidence of the impacts from the project is presented and then in conclusion the future directions that the project participants wish to proceed with are given.

Keywords: Circular economy, East Africa, gender, refugees, resource recovery and reuse

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Agroforestry, challenge or opportunity? Investigating the agroforestry effects in Kohgiluyeh and Boyerahmad province of Iran

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In recent decades major of arable land are extended and there are significant competition for arable land use change. Development of Technology on the hand and Wheat self-sufficiency strategy, lack of arable land, prohibition of national land change and fertile soil of forest land, on the other hand, convert the agroforestry to one of the prevalent methods in less development regions of Zagros forest in Iran. This research investigated the challenges and opportunity of agricultural major strategies and their effects on sensitive ecosystem in Iran. Then by utilising land SAT 5 and 8 images and sentinel images land use changes was analysis by using Object-oriented programming during 1990–2020. The results show that agricultural lands (irrigated and dry farming) have grown by 40 % in the study area. Meanwhile, forest lands show 10 % decrease and rangelands a 6 % increase. The study of land use changes showed two major types of changes for the occupation of forest lands: the first category is the direct conversion of forest lands to pastures and second category is the gradual conversion of forests to agricultural lands (due to cultivation under the mezzanine). The second group is done by mixed cultivation of wheat in forest lands and then the expansion of lands by reducing the number of trees and finally complete capture over time. The results of this study show that the second category is far more dangerous than the first category due to continuous habitat threats and the occupation of a large part of the land. Also, results of research show land use change continuity increase exploitation and erosion, leads to soil erosion, land abandonment, and finally alteration of this land into deserts.

Keywords: Food security, geographical information system, agro-ecosystem, land use change

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The role of aspirations and personality traits for smallholder farmers' decision to adopt agroforestry: Evidence from Kenya

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Current challenges such as climate change and population growth exert increasing pressure on existing farming systems and world food production. The need for sustainable solutions is high. Yet, the adoption of already existing sustainable practices remains low. Agroforestry as one such practice has been proven to combine economic, social and ecological benefits. To understand the adoption process of agroforestry technologies by smallholder farmers, we analyse a primary dataset of 272 households from Kenya. The paper aims to improve the understanding of the adoption process by examining the connected influences of aspirations and personality traits. Structural equation modelling (SEM) is used to perform confirmatory factor analysis on personality traits, the Big Five model, and aspirations. Using path analysis, their impact on the adoption decision of smallholder farming households is analysed. From the SEM, openness and extraversion showed a statistically significant positive correlation with aspirations. This indicates that more open-minded and socially active people tend to also have higher life aspirations. Further, the adoption decision is also positively linked with high aspirations and openness and extraversion. To broaden the understanding, we further assessed these influencing factors in the context of standard household characteristics. Households that adopted agroforestry rely on income from crops and livestock rather than income from business and their members travel more often outside of the village than average. Beyond the binary adoption outcome, adoption diversity and intensity are included. Diversity is a measure of the diversity of the species components of agroforestry households adopted while intensity measures the share of total land under agroforestry. Households that adopted value the observability of the outcome and the availability of inputs and natural resources as most important for the adoption decision. The close connection between personality traits, aspirations and the adoption of agroforestry point to one part of the adoption decision that has previously been underexplored. It could potentially be utilised to improve development projects' design and outcomes once these aspects are better understood.

Keywords: Adoption, aspirations, Big Five, sustainable farming, trees

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Participatory agroforestry design – a flexible approach for locally adapated sytems: Experience from Alto Huayabamba, Peru

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Cocoa agroforestry systems are nowadays broadly promoted, but good guidelines and locally adapted designs are missing. The merely distribution of tree seedlings (by projects or institutions) without any other support leads to very low levels of adoption and farmers' disappointment.

Here we present a method for participatory design of agroforestry systems, based on a process of sharing experiences, visiting inspiring models of agroforestry, definition of individual goals, assessment of resources and evaluation of the opportunities in each individual situation for diversifying production. In the design stage, species and crops to be combined with cocoa are evaluated in a participatory manner between farmers and technicians, based on different criteria like market possibilities, preferences for subsistence production, strata, life cycle, etc. The process can be supported by different visualisation tools, especially if presence in the field is not possible. Feedback from technicians or consultants on the design is critical. Locally available data on yields, prices and labour time needed for different crops can further refine the species and their numbers to be planted.

We have applied this approach for the design of demonstration plots in Peru, Alto Huayabamba, as well as a part of training of trainers, with high rate of engagement and adoption. Inspiration, peers' experience sharing and visual tools were extremely important in the process. The fact that the farmers design their agroforestry farm by themselves with just a guidance of technicians, make the system more approachable, holistic and sustainable compared to traditional agroforestry projects. The method does not limit itself only to cocoa but can also be applied to other crops suitable for agroforestry. Nevertheless, as each of the cases is individual, the time spent on such design makes it challenging to be applied on a large scale at the moment.

Keywords: Adoption, codesign, methodology, planning

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Assessment of current and future suitability of cocoa agroforestry systems in Cameroon

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Climate change is projected to become very limiting for cocoa production in Cameroon which can increase drastically the pressure on forest land as cocoa is already now a major driver for deforestation. Therefore, a comprehensive understanding of climate risks that are associated to cocoa production and change in suitability is key for future resilient land use planning. Agroforestry is a common and promising strategy in the face of climate change impacts on cocoa production due to the reduction of heat stress by providing shade and its various co-benefits. Crop suitability models are used in assessing the impact of climate change on season-long crop production potential and provide important information for projections of production rates. In this study, we developed an approach to assess the vulnerability of cocoa production in agroforestry systems under climate change considering the most common tree species in cocoa plantations in the Central Region of Cameroon. We simulated first the general suitability for cocoa under current and projected climate change and then compared the suitability under an emulated agroforestry system. We considered various biophysical parameters such as shading and micro-climate regulation. Stakeholder and expert's opinion were considered through interviews applying a probabilistic elicitation approach to complete and improve data availability. We modelled future climate projections with Global Climate Models covering the time period 2015–2100 under three Representative Concentration Pathways scenarios of climate change from the Intergovernmental Panel on Climate Change (IPCC). Our results show an increased vulnerability of future cocoa production and important shifts of suitable areas. As farmers tend to plant cocoa also in areas that are limited for cocoa optimum growth, this can have a significant impact on future yield development. Agroforestry increases the average suitability for cocoa production therefore should be considered in building climate-resilient agricultural systems. However, factors as the age or variety of the trees can affect the resilience of the agroforestry system.

Keywords: Agroforestry, Cameroon, climate change, cocoa, suitability modelling

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The role of services and networks for the sustained uptake of agroforestry practices in the Sahel

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In the context of this study a series of econometric estimations were performed to analyse factors associated with awareness, adoption and disadoption of agroforestry in Senegal and Mali. Agroforestry in this context was defined as the active use of trees and shrubs, such as faidherbia albida or piliostigma reticulatum, for improving soil fertility and annual crop productivity. Insights from these analyses stem from a cross-sectional dataset of 2853 households spanning four regions of Mali (Kayes, Koulikoro, Ségou and Sikasso) and one region in Senegal (Niakhar). The dataset was collected during the 2019 and 2020 production seasons and provides a comprehensive resource from which the relationships of key characteristics associated with agroforestry practices were identified. These range from frequently utilised socioeconomic and farm characteristics to aspects concerning social integration and provisioning of financial and advisory services, which are the adoption drivers of main interest of this study. Heckman regression models were specified for both countries to account for exposure bias - the fact that a substantial number of farmers has never heard of agroforestry practices for soil fertility management - and thus improve adoption estimations. The results consistently presented highly significant and positive associations between awareness as well as the adoption decision and key leverage variables related to NGO extension advice and peer learning. Access to extension was also important for increased awareness, while access to credit was associated with higher levels of agroforestry use. The positive associations were clearly reversed when estimating the disadoption decision on the reduced sample of previous adopters. Furthermore, land ownership showed strong associations with adoption. Whilst this approach remains rather exploratory in nature and produces correlations rather than causal explanations, these initial findings nevertheless present interesting considerations for decision-makers and confirm the key role of peer learning in agroecology.

Keywords: Adoption, awareness, disadoption, Heckman model, Mali, Senegal, shrubs, soil fertility, trees

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Shaded cocoa system a bridge for sustainable cocoa production

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Cocoa naturally requires forest shade because it is traditionally shade-dependent. Most smallholder farmers use a variable system of production termed ''agroforestry'' whereby forest trees are selectively thinned so that cocoa and other trees can be planted beneath the remaining canopy. These trees offer farmers a range of agronomic, economic, cultural, and ecological benefits which can help to stabilise or improve farm income and household welfare. Full-sun cocoa is replacing shade production in cocoa-growing regions. It is quite obvious that with dwindling forests for new planting, cocoa agroforestry holds the key to sustainable future outputs and productivity in organic cocoa production. In this study, we evaluated the impact shade levels have on the yield of cocoa under the different cocoa agroforestry systems. Research data were collected from 400 cocoa farmers in the Ashanti Region of Ghana by means of multistage sampling technique through household structured interviews and focus group discussions. Farmers indicated that when environmental issues are not considered, maximum yield is attained per hectare for cocoa farms without shade. Although some farmers are switching to full-sun production, many farmers acknowledge the benefits of maintaining shade in cocoa production. For example, benefits that cocoa farmers attribute to shade include maintaining soil moisture, improving soil fertility, and weed suppression. The average yield per hectare of the full sun/no shade and shaded was 825 kg ha^{-1} and 560 kg ha^{-1} respectively. The yield curve under the no shade/full sun system shows a sharp rise in the yield and followed by a very sharp fall in the yield after age 14. The provision of economic incentives for maintaining shade in cocoa products such as price premiums may increase economic benefits while simultaneously providing incentives to farmers to maintain shade in production. Outreach focusing on the shaded cocoa system may be the most effective way of optimising ecological, economic, and social outcomes to build organic bridges in cocoa production.

Keywords: Agroforestry, cocoa, Ghana, shaded systems

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Driving factors of landscape transformation in Abaya-Chamo sub-basin, Southern Ethiopia

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The human-induced land use land cover change dynamics have extensively changed regional and local landscapes for the several decades. Land use change is typically a function of a selection of different socioeconomic and biophysical variables by different agents. The agro-ecology of Abaya-Chamo sub basin multiplied by the two big rift valley lakes resource played a big role in the transformation of the landscape. Thereby this contribution will highlight how different stakeholders on a landscape has transformed the Abaya-Chamo sub-basin of southern Ethiopia in the last 30 years. Moreover modelling the decision factors of land use changes at smallholder farmers' level and at a higher policy makers' level is of higher importance to convey collective action of active stakeholders in transforming landscape. At various scales several driving forces have different influences on the land use system. Between 1991 and 2021, 10.3 % of the shrub and grasslands of Abaya-Chamo sub basin has been converted to other land uses whereby farm land has taken the largest share in this transformation which has expanded by 7.99 %. During the last 30 years, forest land slashed by 0.49 % and barren land in the sub-basin increased by 0.46 %. The irrigation potential of the area contributed to higher rural urban migration and increased the built up area share of the land cover by 1.16 % in the last 30 years. The settlement in the surrounding resource has been the major driving factors in the land use land cover change of the area through larger conversion of shrub and grasslands to other land uses. The drivers of landscape transformation are economic, political, cultural, demographic and technological forces that influence the decisions of agents involved in transforming landscapes. Modelling the different decision factors of the land use at smallholder farmer level contributes towards farm diversification in agro-ecology practice. Hence the transformation of the landscape contributes to the livelihood of the local community. Furthermore, considering land use decision factor at higher policy makers' level contributes towards amalgamation of different stakeholders actively involved on landscape transformation.

Keywords: Decision factors, diversification, land use, landscape, transformation

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Influence of land use and governance on natural resources in the Diana region, Madagascar

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The population living around protected areas benefits directly from the ecosystem services provided by natural resources. In a country with an agricultural vocation like Madagascar, about 80% of the population lives in rural areas and agricultural activities. In the western part of Madagascar, all protected areas are under pressure due to migratory and anthropogenic phenomena. The Irodo watershed has different types of agricultural vocations including crops (vegetables, tomatoes...), livestock (cattle, goats...), rice, food crops on Tanety (cassava, maize, groundnuts, etc.) and agroforestry/cash crops (cocoa, vanilla, litchi, bananas, etc.) They provide subsistence and income activities for the community living around the protected areas. The regulation and support services provided by the forest whose fertility and soil formation ensure the sustainability of the main activities of people. However, land use patterns and agricultural practices that characterize the region are often linked to the socio-economic characteristics of the population. Agricultural potentials are often determined by these land use patterns. As agricultural practices are still generally based on traditional methods that opt for slash-and-burn crops, the decrease in soil fertility leading to soil degradation induces a decrease in production and thus impacts on food security. There is therefore a link between governance, income from various agro-pastoral speculations, food security and increasing anthropogenic pressures on natural resources. By spatial modelling, natural forest losses can be determined in relation to the mode of land use and thus the mode of governance. This study on linking forest landscape restoration and governance is part of the Tropical Restoration Expansion for Ecosystem Services (TREES) project of Forest for Future (F4F) implemented by GIZ in Madagascar, Ethiopia and Togo.

Keywords: Food security, governance, land transformation, land use, soil fertility

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Agroforestry adoption in the context of clean cooking in central mozambique: constraints and enabling conditions

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Most households in Mozambique use woodfuels to meet their domestic energy demand. The annual population growth of around 3 % puts an additional pressure on remaining forest resources and land use intensification. Therefore, sustainable woodfuel supply chains are vital to meet households' woodfuel demand and to protect natural ecosystems. Agroforestry is an agro-ecological practice which, together with improved and clean cooking stoves, can potentially reduce pressures on natural forests. However, little is known on the quantification of on-farm produced fuelwood and the adoption of agroforestry systems by smallholder farmers. In this study, we assess the presence or absence of the main factors necessary for transitioning to agroforestry systems in two villages in Central Mozambique, Zambézia Province, Gurué district, namely, Lioma and Mepuagiua. We aim at understanding how farmers' intrinsic motivations, governmental regulations and prevailing social norms affect the adoption of agroforestry systems in the study area. The study assessed the adoption level of 129 farmers of three main types of agroforestry systems (agrisilvicultural, silvopastoral and agrosylvopastoral systems) including the purpose and species used. In addition, we analysed farmers' demand for agroforestry and the potential for a widespread implementation of agroforestry practices in the study area. The results suggest that agrisilvicultural is the most predominant system in the study area. Furthermore, social norms and government regulations do not restrict adoption; however the policy in place facilitates and incentives non-agro-ecological farming. Lack of finance and investment possibilities are limiting the adoption of agroforestry systems, whereas woodfuel shortages have been identified as drivers of adoption.

Keywords: Biomass energy, clean fuels, renewable energy, sustainable cooking

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Biodiversity and food production in agroforestry systems

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Intensive agriculture is one of the main drivers of biodiversity loss. Agroforestry systems and organic farming have the potential to maintain and promote biodiversity. It is often argued that it comes at the cost of losing productivity. In Bolivia, a long-term trial was established in 2008 to evaluate the agronomic, ecological and economic performance of different cacao production systems, i.e., monocultures and agroforestry systems under organic and conventional management and a complex agroforestry system without external inputs. Here we present our results on biodiversity and food production. Overall, we found that agroforestry systems and organic farming support both. The bird diversity was positively related to the vertical complexity and tree diversity, decreasing from complex agroforestry to monocultures. The ant species diversity did not vary among systems; however, the species composition did. The herbal plant diversity and composition differed mainly between organic and conventionally managed systems. Widely distributed herbal species, including exotic species, were more common in non-organic cacao production systems. In addition to species diversity, cacao production systems also affected biological interactions. For instance, higher pollinator abundance was found in more complex agroforestry than monoculture and cacao trees growing in agroforestry showed a more efficient water use by reducing the transpiration rate. Cacao yield was similar in both organic and conventional agroforestry systems, but slightly lower in the organic monocultures over the whole years. Cacao production was higher in the monocultures compared to agroforests, but when considering all the crops, agroforesty systems had 3–4 times higher total production (in dry matter) than the monocultures.

Keywords: Agroforestry, ants, biodiversity, birds, cacao, herbs, long-term trial, organic farming, pollinators, yield

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Bioeconomy based on agro-ecological principles: Integrated approaches to food and energy security

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Rising food and fuel prices exacerbate food and energy insecurity among low-income households in both the Global South and North. This is particularly a challenge for smallholder households whose limited access to land makes it difficult for them to meet their needs for food, income, and energy. They strongly rely on woody biomass for energy, while the production of firewood and charcoal is often associated with unsustainable management of forest and tree resources. Policy and development interventions tend to address food and energy issues in isolation. In reality, however, they are intertwined.

In response, we propose integrated approaches to food and energy security which focus on bioeconomy opportunities and are based on agro-ecological principles. Such opportunities are identified with a view on value chains for diverse bioeconomy products, such as food crops, woody biomass for energy, and non-timber forest products. In terms of agro-ecological principles, emphasis is put on measures to increase soil fertility and the diversity of plant and animal species, and on improving pest and disease control, water management, and the combination of multi-structured land uses.

We illustrate the versatility of such approaches with examples from across diverse geographies and settings. In sub-Saharan Africa, a balanced agroforestry approach considering demand and supply dynamics in wood energy value chains, food production, recovery of waste bioresources for energy, and the use of improved kilns and stoves has significant impact on improving smallholder livelihoods and reducing the pressure on forests. In Southeast-Asia, integrated approaches to climate-smart agroforestry produce a variety of food, energy and biomaterials while restoring degraded landscapes. In the western Balkans, the combination of short-rotation plantations of fast-growing tree species (willow, poplar), agroforestry borders, and permanent tree areas enhances energy security, income generation, and biodiversity in land-

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scapes otherwise dominated by the production of wheat, maize, and sunflowers, while at the same time contributing to the urgently needed energy transition away from coal.
We conclude that integrated approaches to bioeconomy based on agro-ecological principles are an overlooked pathway to produce healthy foods, provide sustainable energy, reduce greenhouse gas emissions, create equitable jobs and prosperity, and conserve biodiversity at global scale.

Keywords: Agroforestry, biodiversity, bioeconomy, energy transition, food security

Diversification strategies for sustainable cocoa production in Côte d'Ivoire

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In West Africa, the introduction of cocoa farming has led to the destruction of large areas of forest. Over the years, cocoa alone is rarely sufficient to generate a subsistence income for farmers or to support their families. Thus, sustainable agricultural intensification and the integration of agroforestry into cocoa plantations has become an imperative in order to preserve biodiversity but without compromising agricultural production, food security and development objectives. Indeed, agroforestry is introduced to facilitate diversification and support of production, and increases the resilience of rural landscapes and livelihoods. Introducting of agroforestry systems further follows the notions that when taking into account the different cropping practices, the economic profitability of the by-products of agroforestry systems and their usefulness leads to a fairer and more efficient design for sustainable production. Current research mainly focuses on agro-economic impacts of agroforestry systems. Little is known about agroforestry systems' contributions to producers' livelihoods, and their value for domestic consumption. This study aims to narrow this gap by analysing different household-scale cropping systems and their carbon stocks, the socio-economic utility of trees associated with the different production systems, and the determinants of adoption of agroforestry practices. To this end, floristic inventories of 625 m^2 in 150 cocoa plots and a mapping of the different land use systems, as well as socio-economic surveys will be carried out among 300 households in five localities of Côte d'Ivoire (Abengourou, Aboisso, Agboville, Yamoussoukro and Divo) targeted by the Pro-Planteurs project. Quantitative and qualitative analyses of variables and statistical tests will be carried out for this purpose using R software. Thereby, the cropping systems are mapped and characterised according to their floristic characteristics and their contributions to socio-economic indicators and adoption drivers of agroforestry practices by cocoa farmers are identified. The results will help to design and implement agroforestry systems with better market potential and land profitability adapted to the context.

Keywords: Agroforestry, cocoa, Côte d'Ivoire, household, livelihood

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Systematic integration of crops, shrubs, trees and livestock in the West African Sahel for resilient livelihoods (SustainSahel)

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In the West African Sahel land degradation and soil erosion severely affect more than 80 % of range- and farmlands. In addition to social, economic, political and cultural drivers—such as unsecure land/tree tenure—land is degraded by ecological, agronomic, and biological factors such as heavy soil weathering, short rainy seasons, low and erratic rainfall, low biomass productivity and overgrazing. SustainSAHEL is a recently initiated (September 2020) Horizon 2020 funded project conducting biophysical and socio-economic research that can be used by the people of the West African Sahel to build capacity and develop networks to help them create sustainable dryland farming systems and viable (rural) livelihoods. The overall objective is to enhance the resilience and intensification potential of smallholder agricultural farming systems to climate change through scalable innovations on crop-shrub/tree-livestock (CSL) integration. Systems approaches are a core concept of SustainSAHEL and reflect the linkage of biophysical, socio-economic, cultural and political realities. SustainSahel is assessing adoption and scaling potential of improved CSL integration, while simultaneously optimising proven technologies, tackling socio-economic constraints for adoption and contributing to local economic revival. Investigations on CSL, are being conducted through 15 on-station and 80 on-farm experiments and demonstration plots across Senegal, Mali and Burkina Faso. We are investigating drought resistant shrub teams that are in synchrony with livestock requirements, and reduced tillage options that enhances the soil water capture and holding capacity. At the regional level, landscape modelling scenarios are analysing the promoted systems' resilience to climate change in West Africa. The first-year results from the field and on-farm experiments are currently being collected/analysed and some will be presented at this conference.

Keywords: Agroforestry, crop-shrub-livestock integration, soil health

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Trees for people and environment

Carbon storage potential in savannah woody vegetation

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Global drylands have been highlighted as a possible carbon sink and roughly 36 % of current worldwide carbon stocks are stored in drylands. While the carbon storage per unit area is low compared to other ecosystems, the large area in question gives dryland carbon sequestration a global significance. Apart from their carbon sink potential, drylands are increasingly being recognised as productive and important ecosystems, with their inhabitants largely relying on agroforestry and cattle husbandry.
In rural Africa, land-use changes often occur along two divergent pathways of land conversion, thereby turning non-utilised savannah into either agroforestry sites or nature conservation areas. Both transformation pathways are driven by aspirations to harness ecosystem services, be it food security and feed production on the one hand, or biodiversity conservation and tourism income on the other. What both pathways have in common, though, is the expected reduction of woody aboveground biomass and hence carbon storage potential, be it through wood clearing and fires or megafauna browsing impacts. To estimate current and future land-use change impacts on carbon storage in African savannahs we conducted tree inventories along both land-use change pathways and analysed carbon losses to various disturbance agents. The chronic disturbance regime and diverse modes of land-use first required us to develop a new protocol for tree inventories in order to reflect the disturbance impacts.
Results indicate that a majority of growth forms and individuals in savannah vegetation could only be assessed if measurement protocols were adapted to the conditions of a disturbance-prone ecosystem and contained a damage assessment for trees and shrubs. Furthermore, our damage assessment demonstrated that one third to half of all woody aboveground biomass (and carbon stored therein) was lost to disturbances. Still, carbon certificates should be explored as a possible third income source for local livelihoods in addition to agroforestry and nature conservation.

Keywords: Carbon storage, disturbance ecology, savannahs, woody aboveground biomass

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How to correctly monitor seedling survival rate in a (semi-)arid Sahel environment at low cost

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For more than a decade, the Great Green Wall initiative has been trying to counter desertification and land degradation in the Sahel region of Africa. Of late, the initiative's intervention scope has been widened to southern Africa. In all cases, local populations are invited – or goaded as some would claim – to plant trees and shrubs from seed or through nursery-grown plantlets. Most organisations, be they official governmental or non-governmental, that finance and supervise/manage these kind of activities, however, give the impression they are only interested in keeping stock of hectares prepared and planted, but do not monitor nor evaluate survival rates of seedlings or 'real' reforestation success rates, so that it is difficult to know how great the green wall is after all these years...

The reasons mentioned mainly centre on lack of cheap, cost-efficient monitoring techniques. Traditional field-collected data are labour-intensive, and also need lots of well-trained people in the field. In the absence of accurate, precise and highly-performant satellite imagery-driven systems, we propose a sampling strategy where high-resolution drone-generated images would be collected on a regular basis, and analysed through algorithms (and eventually machine learning/artificial intelligence) that would allow to detect, earmark and monitor growth and development status and rate of even the smallest seedlings. Theory will be matched with concrete field monitoring-generated data from northern Senegal. Distinguishing small tree seedlings from the surrounding wildlings and herbs/grasses that start growing with each rainy season, remains a challenge that current technology and monitoring systems have not been able to solve...

Keywords: Africa, Great Green Wall initiative, land degradation, monitoring and evaluation (M&E), reforestation

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Cedrella odorata stand structure, carbon stocks, and understorey species diversity along topographic gradients in the deciduous forest zone of Ghana

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Topographic heterogeneity often results in ecological gradients across geomorphological positions. Single species tree plantations established across different topographic positions may respond differently and exhibit varied stand characteristics. However, within West Africa, there is limited information on variability of plantation stand attributes along topographic gradients. This study examined the structural characteristics, carbon stocks and understorey woody species diversity of relatively older *Cedrella* plantations on three topographic positions within the deciduous forest zone of Ghana. About 15, 40×40 m plots were surveyed in 29-year-old *Cedrella odorata* plantations located on ridge summits, flat terrain and Valley-bottoms in the Tinte Bepo Forest Reserve, Ghana. Data were analysed using ANCOVA and Bayesian modelling of diameter distribution.

Diameter at breast height ($p < 0.0001$), total height ($p < 0.025$), and stem density ($p < 0.001$) were significantly different among the three topographic regions. Trees on the flat terrain had the highest diameter at breast height, stem density, basal area, biomass carbon and volume. Slope explained 63 % of the total variability in the *C. odorata* stem density . Bayesian modelling of diameter distribution revealed that the 3-parameter Weibull function better fitted the diameter distribution of the trees on the ridge crest/summit while the Johnson SB was more appropriate at the flat terrain and the valley bottom. Understorey woody species abundance and richness did not differ between topographic regions. Shannon H for understorey species were 1.90, 1.90 and 1.66 for the valley, flat terrain and ridge crest, respectively. *Cedrella odorata* was the most abundant species in the understorey of the ridge crest and flat terrain while *Mansonia altissima* was most abundant in the valley bottom. Aboveground biomass carbon stocks differences were relevant but not significant ($p < 0.05$) among topographic positions.

It is concluded that local topography can severely alter plantation stand structure, leading to different distribution models being adopted at different topographic positions. Furthermore, though understorey woody species diversity may be similar among topographic positions, species composition and functional/trait diversity differences reflect the microhabitat conditions resulting from topography effects. Climate mitigation benefits of these plantations are similar to existing natural forest. Hence, appropriate management at different topographic positions are required.

Keywords: Climate mitigation, plantation, topography, understorey, woody species

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Perennial monocropping of khat decreased soil carbon and nitrogen relative to multistrata agroforestry and natural forest in southeastern Ethiopia

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Monocropping of perennial cash crops providing livelihood for smallholders is replacing native forest throughout the tropics, but there is no direct empirical evidence on the impact on soil organic carbon (SOC) and nitrogen (N) relative to multistrata-agroforestry-based cash cropping. In particular, the impact of the conversion of forests and multistrata-agroforestry-based cash cropping to a rapidly expanding perennial monocropping of khat (*Catha edulis* Forskal) is not known. We investigated the potential of cash cropping integrated in multistrata agroforestry to alleviate SOC and N loss from converted native forest, relative to cash monocropping. We assessed empirically SOC and N stocks in the 40-cm-deep soil surface layer of three matched adjacent plots of native forest, multistrata agroforestry and perennial cash monocropping, within nine replicate groups of the three land uses. The fixed mass method was applied. The estimated rates of the annual SOC and N losses were 3.0 and 3.4 times greater, respectively, in areas converted to khat monocropping than in agroforestry systems producing both coffee (*Coffea arabica*) and khat. Additionally, the carbon and N contents in leaf litter and fine roots were greater in agroforestry than in khat. The results indicated that multistrata-agroforestry-based cash cropping maintains most of the SOC and N stocks of converted native forests lost in conversion to cash monocropping khat than in agroforestry-based cash cropping. This warrants economic incentives to prevent the loss of the current stocks, while enabling cash crop income by smallholders. Reducing forest SOC and N stock decline in agroforestry through system management deserves attention as well.

Keywords: *Catha edulis* (khat), East Africa, monocropping, native forest, soil carbon, soil nitrogen

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Improving water use efficiency for a more sustainable production of *Macadamia* ssp. in South Africa

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Macadamia is currently the most expensive tree nut in the world with a continuously rising demand. South Africa is the world largest producer of macadamia nuts, with orchards increasing by more than 5,000 hectares annually. However, the ongoing expansion of macadamia growing areas comes with environmental downsides, especially in terms of water consumption. Increased use of irrigation water for achieving high nut yields under conditions of periodic droughts and erratic rainfall, puts additional pressure on the limited water resources of South Africa - which are further threatened by climate change. For a more sustainable macadamia production it is paramount to improve water use efficiency.

With this in mind, we aimed to characterise and quantify macadamia tree water use under different environmental conditions (rainy vs. dry season) and considering different cultivars and tree ages.

Data on macadamia transpiration (measured as sap flux density), soil water content and microclimatic parameters was recorded through intensive on-farm experiments over two consecutive years from a total of 20 trees belonging to different cultivars ('Beaumont' and 'HAES 849') and age classes (intermediate vs. full-bearing). Daily tree water use (calculated as the integration of hourly sap flux density over sapwood area) and transpiration patterns as affected by climate and soil water conditions were compared. The most important drivers of macadamia tree transpiration were then determined using a multiple regression approach.

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Our results show that macadamia tree water use significantly varies between cultivars and under different environmental conditions. Full-bearing 'Beaumont' and 'HAES 849' trees recorded daily water use quantities of 24.5–29.6 and 23.9–36.5 litres d^{-1} respectively, between dry and rainy season. Microclimate largely controls macadamia tree transpiration rate: a threshold of ca. 2 kPa of vapour pressure deficit (VPD) was observed beyond which transpiration was limited regardless of soil water content. This indicates a conservative (isohydric) water use behaviour of macadamia trees, which do not use more water under conditions of high VPD. Therefore, applying large irrigation amounts under such conditions would lead to overirrigation. Hence, there is scope to increase macadamia tree water use efficiency by reducing irrigation amounts, especially during periods of high atmospheric demand.

Keywords: Ecophysiology, hydricity, irrigation, sap flux density, South Africa, transpiration, vapour pressure deficit

Effects of thinning on growth performance of teak (*Tectona grandis*) plantations in Tain II forest reserve, Ghana

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Plantation establishment has been promoted in the tropics in the last 4–5 decades in a bid to mitigate climate change, timber deficit, and biodiversity loss, as well as restore degraded forests and provide employment incentives to fringe communities. Practitioners require technical information about appropriate cost-effective silvicultural techniques that can achieve higher productivity. In Ghana, government incentives have promoted the commercial establishment of teak and other species plantations, yet information on tree response to silvicultural management is still scarce. The present study evaluates the effects of thinning intensity on the growth response and pruning requirements of teak plantations, two years after thinning. The thinning trial was conducted on a four-year-old stand with initial stocking of 1111 trees per hectare in the Tain II forest reserve of Ghana. Four thinning intensities: 50 %, 30 %, 0 % thinning intensities and 50 % de-crowning were the treatments arranged in a completely randomised design. Each treatment had four replicates. ANOVA output for data collected two years after thinning revealed statistically significant difference between the treatments in DBH ($p < 0.012$) and volume ($p < 0.017$) whereas total height and basal area were not significantly different. The highest DBH, volume, height and BA per tree were found in the 50 % thinning intensity (15.57 cm, 0.13 m^3, 12.13 m and 0.02 m^2 respectively) while the lowest was found in the control. Maximum mean annual increment of DBH, height and volume were respectively, 2.66 cm, 2.34 m and 16.32 m^3 ha^{-1}. Increasing the thinning intensity significantly increased the number of epicormic shoots ($p = 0.0397$), hence increasing the pruning requirement. It is concluded that 50 % thinning intensity best favours the growth of residual trees but it increases the pruning requirements and ultimately the pruning costs. Evaluation of this trial over a longer time period is paramount to validate these preliminary conclusions.

Keywords: Epicormic shoots, plantation, pruning, residual trees, thinning intensity

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Diversity and genetic structure of natural populations of *Cedrela odorata* in Sierra del Lacandón, Guatemala

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Cedrela odorata L., one of the most important Neotropical timber species, is threatened by deforestation and unsustainable logging in many parts of its natural range. Information on patterns of genetic variation helps plan reforestation and plant genetic resource conservation activities. However, to date, this information is not available in Guatemala. This study reports on genetic diversity between and within the four populations of *C. odorata* located in the Sierra del Lacandón in northern Guatemala, based on eight highly polymorphic microsatellite markers. There were a total of 93 alleles found throughout the eight loci, with an average of 6.38 alleles per locus. The level of genetic differentiation was low (Fst = 0.022), indicating high gene flow between populations (Nm = 3.56), while genetic diversity was high (He = 0.721, Ho = 0.629). However, the level of inbreeding was determined to be significant (Fis = 0.127), which is a strong indication of genetic erosion. One of the six G'ST(Nei) pairwise comparisons indicated no genetic difference. We discovered a mixture of *C. odorata* trees from various populations using UPGMA hierarchical cluster analysis. Molecular analysis of variance revealed that only 3 % of the variation is due to the effect between populations, while 97 % of the variance is within populations. Compared to other studies, levels of connectivity between populations and the degree of genetic diversity are higher. The high genetic diversity found in the *C. odorata* germplasm suggests that it might be a valuable source of variable alleles that may be used for breeding programmes for this timber species. We suggest maintaining efforts to avoid population reduction through deforestation and illegal extraction, thus reducing the constant risk of erosion due to genetic drift.

Keywords: Gene flow, genetic erosion, genetic variability, inbreeding, Spanish cedar

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Morphological characterisation of *Ricinodendron heudelotii* (Baill.) Heckel in Cameroon – potential for domestication

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Ricinodendron heudelotii (Baill.) Heckel, also known as 'Djansang', is found in the semi-dry wooded-savannah zone of Central and West Africa. It is one of the economically most important indigenous fruit tree species with potential for use in agroforestry systems, but it is also considered underutilised and under-researched. The kernels, which are mainly used to produce edible oil, are reported to be one of the most traded non-timber forest products (NTFPs) in Cameroon. Despite its importance, the species is still harvested from the wild/ natural populations. It lacks basic information on morphological diversity which is crucial for its domestication process. The objective of the study was therefore to evaluate morphological variability in *R. heudelotii* fruits and seeds across two regions in Cameroon, namely, the Southern and Central regions. Data were collected from a total of 50 individuals of *R. heudelotii* from four geographical populations. Ten fruits per tree were collected, evaluated and all seeds were characterised for basic morphotypes. Fruit weight, length and width, seed weight, length and width, and number of seeds per fruit were analysed using PCA, kmeans and one-way anova. The results revealed clustering roughly based on geographic origin, however, significant variations in fruit size were likewise observed among individual trees sampled ($p < 0.05$). A positive correlation was observed between fruit size and seed weight. Variations could have genetic basis that may be reflected in molecular DNA analysis currently in progress. Selection and improvement programmes focusing on trees with large fruits could lead to higher yield of seeds for oil production.

Keywords: Domestication, fruit tree, genetic diversity, morphotypes, non-timber forest products, seed oil

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Understanding the relationship between morphological traits and genetic diversity of *Vitellaria paradoxa* (Sapotaceae) in Cameroon

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Vitellaria paradoxa C.F. Gaertn is a keystone species of the parkland agroforestry system that extends across the wooded savannah of Cameroon, providing a range of environmental services at the landscape level and nutritional and livelihood resources for smallholder farming communities - particularly the rural women who gather its nutritious fruit, and process the kernel into shea butter. At the same time, the species is classified as vulnerable. However, previous studies were limited to the phytochemical content of the shea butter, and they could not address the evident morphological diversity of the species, including fruit traits - identified as a significant driver for farmer selection and sustainable management of the species on farmed parkland. Of particular note is a provenance found only in the West region of Cameroon, which appears to be facing extinction. But other origins are also distinctive according to traits. The general objective of this study was to assess the morphological features in the characteristics of the shea tree and fruit in the selected sampling locations in Cameroon (western highlands, Guinean high savannah, Soudano-Sahelian). A total of 167 trees were randomly selected, and 2,211 kernels were collected at three agroecological sites. The trees sampled in the three populations were 60, 65, and 56, respectively. The measured fruit traits were kernel length, weight, width, DBH, crown diameter, and height. The data was analysed using principal component analysis and hierarchical clustering. Preliminary results revealed three dominant clusters related to the tree and kernel traits. Kernel weight, width, and length are correlated, while DBH, crown diameter, and tree height are also positively correlated. Significant variation was observed in kernels parameters among and within sites ($p < 0.05$). The ongoing DNA genetic characterisation with single nucleotides polymorphisms molecular markers will help to explain this variation. The results will improve (1) the understanding of tree and morphological diversity, (2) develop effective management strategies for sustainable use and conservation of this vulnerable underutilised species and (3) preserve the associated genetic biodiversity for breeding purposes.

Keywords: Biodiversity conservation, clusters, tree breeding

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Functional traits characterisation of popular shade tree species in cocoa agroforestry systems in Ghana

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Climate change is increasingly threatening agriculture and global food production and the strongest impacts are expected in tropical smallholder systems such as cocoa farms in Ghana. Cocoa agroforestry systems are often seen as an opportunity to adapt to and mitigate the impacts of climate change while sustainably increasing production. Favourable microclimate under the shade trees buffers extreme weather conditions from the cocoa trees whilst sequestering atmospheric carbon. However, it remains controversial whether shade trees have a positive or negative impact on cocoa yields, as previous studies have shown both higher and lower yields in agroforestry systems compared to monocultures. Given the suggestion that the effect may also depend on the shade-tree species' specific traits, this thesis examines the above-ground morphology (DBH, tree height, canopy height, form, area and health) and below-canopy microclimatic conditions (solar radiation, temperature and relative humidity) of eight locally common shade-tree species in cocoa agroforestry systems. Effect of these traits on the development and productivity (DBH, tree height, canopy health, leaf CCI, flower intensity, cherelles, pods, black pods, pod sizes and weight) of surrounding cocoa trees in three different impact zones were further analysed. The central question is whether significant differences between the impacts of the different shade-tree species exist and, if so, which specific traits can be considered as the most important for productive and climate resilient cocoa agroforestry systems. Measurements are conducted from April to June 2022 in ten smallholder cocoa agroforestry systems in the Ahafo region, Ghana. Results are still pending, although an initial review of preliminary data already indicates differences between some species. The final results will allow a better understanding of species-related differences in cocoa agroforestry system resilience to climate change impacts as well as cocoa tree development and productivity, which may even serve to reconsider existing species recommendations.

Keywords: Climate-smart agriculture, microclimate, shade-trees

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Germination study of three Fabaceae species, endemic of south-western region of Madagascar

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In the south-western region of Madagascar, the Fabaceae family is commonly used by the local population for different purposes along with their ecological importance. Its natural regeneration rate is very low because of the problems related to physiological and morphological seed dormancy and other ecological factors. To overcome these difficulties, *ex situ* multiplication of seedlings is essential to ensure the sustainable use of the Fabaceae species which are of socio-economic, ecological and cultural importance. Thus, a germination test was undertaken for three endemic woody Fabaceae species encountered in Tsimanampesotse National Park such as *Acacia bellula*, *Delonix floribunda* and *Tetrapterocarpon geayi*. The aims of this study is to identify the optimal conditions for seed germination and seedling growth. Four factors or treatments closely related to seed germination and seedling growth were tested: pre-treatments, seed size, substrates and water salinity. The results revealed that these treatments showed significant effects on germination rates for all species studied. Manual scarification led to the highest germination rate for *A. bellula* (60.2 %), *D. floribunda* (58.7 %) and *T. geayi* (87.9 %). For A. bellula, the largest seeds gave the highest germination rate (70.33 %). For *D. floribunda* and *T. geayi*, the highest germination rate were obtained with medium size seeds, with 67.06 and 77.4 % respectively. The results showed that only *A. bellula* tolerates the salinity of the water at the time of germination and growth, with a germination rate of 80 %, corresponding to the dose of 10 g L^{-1} NaCl. For *D. floribunda* and *T. geayi*, the germination rate at 10 g L^{-1} NaCl dose is low, with 1.40 and 57.05 % respectively. *D. floribunda* is well adapted to all types of substrates tested, with a germination rate of about 80 %. Calcareous soil was the most favourable not only for germination, but also for growth and viability of the seedlings of the two species. Because of their simplicity and low cost, these techniques are recommended for the future production of seedlings in this region, while preserving the sustainability of these species.

Keywords: Fabaceae, germination, growth, seed, Tsimanampesotse

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Host functionality as a driver in the modularisation of fungi-roots association

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Tropical rainforests are the most diverse biome on our planet, composed of a mosaic of micro-habitats highly associated with a heterogeneous distribution of organisms. This includes the rhizosphere as a host for thousands of biological organisms, such as plant-associated microbial communities. The plant-microbiome interaction modulates plant health through the recruitment of specific microbial communities that act as suppressing antagonists (such as predators, and parasites) and inhibit pathogenic activities. Host-fungi associations are likely to be modulated by plant functional groups, instead of reflecting individual species interactions. Host characteristics have proved to be deciding factors for the selective distribution and composition of the fungal community, and therefore, decisive in the structuring of co-occurrence networks. Our main interest lies in non-random associations between root-associated fungi and host plants. We hypothesise that network compartmentalisation of rhizosphere fungal community composition and plant species host community will be explained by host functionality. We employed amplicon sequences of roots and fungal communities from 31 samples obtained from five soil cores (15 cm depth, 4 cm diameter) extracted from 5 × 5 m subplots evenly sampled within the established research plots (50 × 50 m) located in four land-use types (lowland rainforests, jungle rubber, rubber, and oil palm plantations) in Jambi, Indonesia. Our preliminary results based on the reconstructed modules uncovered an association between specific plant functional groups and particular fungal guilds, i.e. herbaceous or shrub alien taxa (*Clidemia, Asystasia*, and *Centotheca*) grouped together with the monoculture crop *Elaeis guineensis* and appear to be correlated with pathotrophic fungi. *Hevea brasiliensis* clustered together with another cash crop *Dioscorea persimilis* and other species such as *Uvaria leichhardtii* and *Spatholobus pulcher* and showed only a few associations with AM and saprotroph fungi. Root traits such as specific root length and root diameter, together with the phylogenetic distance of host species are expected to explain non-random associations between roots-fungi.

Keywords: Co-occurrence network, fungi, Indonesia, roots

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Planting carbon-certified community agro-forests in the African Sahel. A strong brick in the great green wall

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Reforestation is a key strategy in climate change mitigation and adaptation. However, land restoration through tree planting is constrained in areas where forests heavily compete with other land uses such as agriculture. This a to a much lesser extent the case in semi-arid regions, which are sparsely populated and where land is mainly used for nomadic grazing. Since 2010, Entrepreneurs Without Frontiers (OZG), a Belgian NGO, plants agroforests in the semi-arid African Sahel, thus creating an environment which stores carbon (at a rate of 3.5 tons per ha per year), halts desertification, allows agriculture to thrive again (in conjunction with tree plantations), improves water management and availability, enhances biodiversity and creates sustainable employment thereby consolidating local livelihoods. OZG's activities contribute to the Africa Union-led Great Green Wall initiative which aims at scaling up reforestation activities as a means to stop desertification on the African continent. In semi-arid areas, reforestation is severely hampered by drought stress. To relieve this problem, OZG harvests rainwater through the creation of "half-moon" micro-catchments (i.e. semi-circular bunds) using a specially designed plow (Vallerani System). The latter half-moons, each collecting around 1200 L of rainwater per rainy season, are subsequently sown with locally collected (and appreciated) drought-tolerant tree seeds. Using this system, OZG has successfully planted 10,000 ha of forest between 2010 and 2017 in northern Burkina Faso. The latter experience was a proof-of-concept which has led to more than 2000 ha of semi-arid degraded land being reforested today in Senegal, where the organisation started its activities in 2019. Sustainability of OZG's reforestation activities is ensured through third-party certification of biomass accumulation in reforested areas, in which each issued carbon credit represents 1 ton of sequestered carbon. Further, in OZG's vision and approach newly created forests are managed by, and provide benefits to, the local community. Communities themselves select the forest tree species to be replanted. As a result, the reforested trees are well-adapted to the local ecology, enhance biodiversity and generate numerous livelihood resources in the medium and long term (livestock fodder, horticultural products, non-timber forest products, etc.), thus ensuring longevity of the newly created agroforests.

Keywords: Burkina Faso, carbon sequestration, pastoralism, reforestation, Senegal, Vallerani

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Extension and support services for utilisation of farmed and wild forest products: Experiences from Malawi

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Empowering and encouraging farmers to grow trees and utilise farmed and wild forest products through extension and support services provides many diversified benefits for agroecological farming. The role of extension and support services to farmers to increase tree production in farming fields and to sustainably utilise farmed and wild forest products was investigated in a cross-sectional study targeting 373 smallholder households in 2017, in Lilongwe district which has diverse farming areas, from close to vast but dwindling forests to expansive farming fields having fewer trees. Multistage sampling was used to select the farmers from four ecological zones with a wide range of potentials and limitations for tree production and non-timber-forest-products. Results showed that 72 % of all farmers accessed extension services and 67 % of all farmers grew trees in their fields. Approximately 41 % of farmers grew fruit trees for home consumption while only 2 % grew them for sale. Lower access to extension services reduced the number of farmers growing trees in their fields. Stakeholders' support for input access was low, as 80 % of farmers sourced seedlings through own collection, 33 % allowed trees to either regenerate or left volunteer seedlings to grow, 3 % bought the seedlings, 3 % were given seedlings by friends, 1 % got seedlings from Government or NGOs. Farmers reported that access to tree seedlings was a medium to severe problem. Wild fruit collection was practised by 63 % of farmers. Some of farmers reasons for eating wild fruits were "food diversification", "fruits were locally found", "no need to purchase", "preference", and "need to supplement food during lean season". Wild vegetables were also collected and consumed by farmers, such as okra (64 %), mushrooms (24 %), and leafy vegetables (6 %). The study proved that tree and wild forest based agroecological farming can feed communities. Increasing extension access and support service provision can broaden the farmer access to farmed and wild forest products for food and potentially for sale of surpluses.

Keywords: Farmer preferences, tree seedlings provision, wild and farmed food

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Effects of land use on tree species diversity in different agro-ecological zones of Ghana

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The understanding of changes in plant species' responses to the interactive effect of land use and climate is not only an important area of research, but could also inform on the effect of such interactions on the composition and structure of future plant biodiversity. We hypothesize that rainfall and land use affect the composition and diversity of tree species and soil fertility attributes. We investigated the effects of land use along an aridity gradient on the population structure and diversity of woody vegetation and on soil fertility attributes in Ghana. The study was performed in: i) the wet evergreen forest zone, ii) the moist semi deciduous forest zone and iii) the dry semi deciduous zone, following a gradient of increasing aridity. In each zone, we compared protected forest areas with the surrounding non-protected agriculturally used areas. Ten survey plots of 50 m × 20 m (0.1 ha) were randomly selected in each of the six site (60 observation plots in total). In each plot, composite soil samples from top soil (020 cm) were taken for physico-chemical analyses. Species richness and Shannon-Wiener diversity index were calculated based on species identities and relative abundance in a vegetation layer. Soil fertility attributes was measured for the different land use types in all the ecological zones.

Tukey multiple comparisons of means at 95 % confidence level among different land use types showed significant difference in species richness and Shannon Wiener diversity index between land use types (protected forest and croplands) in each ecological zone. We observed tree species diversity increased in a gradient of decreasing aridity / increasing rainfall regimes. Protected forest areas showed highest levels of tree taxonomic diversity with varying degree among aridity gradients. Soil attributes (pH and C:N ratio) were observed to be significantly different and more homogeneous in dry and moist semi deciduous ecological zones in both land use types compared to Wet evergreen zones. The outcomes of this study depict the rapid reduction of tree species diversity as a result of agriculture. Hence, the development of agricultural systems where more trees are incorporated on croplands is highly suggested.

Keywords: Climate change, diversification, ecosystem service, forestry, nutrient cycle

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Analysis of the potential of environmental and social standards for strategy and economic performance of food processing SMEs in Central Asia

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Natural forests of Central Asia (CA) play an essential role in the livelihoods of surrounding populations. The products harvested from those forests, such as walnuts, mushrooms, wild fruits, berries, firewood, medicinal plants, hay, and other non-timber forest products (NTFP), constitute a primary source of income and livelihood for many private households in the region. Because of this, rural communities often extract NTFPs in high amounts, thus, overexploiting and destroying local forests. Integrating agroforestry (AF) practices could be a worthwhile alternative to bring significant environmental and economic benefits. Especially within the context of the growing global trend toward the consumption of properly grown and processed healthy food and a rising standard of living and awareness of the population of CA. However, small and medium farmers and processing enterprises (SMEs) often do not fully exploit and benefit from such opportunities due to limited knowledge and funding, uneven value distribution, uncoordinated public policies, and the absence of standards for most local AF and NTFP food products. A solution that can benefit and bridge environmental and social goals in AF integration is integrating environmental and social standards. Based on the above, the current research aims to analyse the extent and economic benefits of environmental and social standards for the strategy and economic performance of AF and NTFP food processing SMEs in CA. This paper consists of several sections. First, the paper will provide a literature review to understand how various environmental and social standards affect different participants in the food value chain. Then, the analysis of the current situation related to environmental and social standards in CA will be presented. Last, the empirical part will provide the analysis of local NTFP and AF producers based on the comparative case study method and the research of demand for the AF environmentally and socially sustainable products based on a market survey. Based on the findings of the research, theoretical and practical implications are expected in the form of developing 1) a model for the certification of agri-food SMEs according to selected standards and 2) a basis for monetizing selected standards for the benefit of AF systems.

Keywords: Agri-food processors, agroforestry, Central Asia, certification, environmental and social standards, non-timber forest products, SME

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Effects of agroforestry on rangeland conditions and animal performance

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The present study was initiated with the objective to investigate the effect of agroforestry and seasonality (during two successive years) on five range species using *moringa* tree in the model. The study utilised an enclosure located in a peri-urban area in Khartoum state. Measured parameters included days to germination, flowering and seed setting as well as productivity expresssed in dry matter yields (ton hectare^{-1}). The nutritive value was analysed for pre- and post-flowering physiological status. Soil sampling was done before and after plantation. 9 rams were divided into 3 groups, one fed *moringa* alone, the other fed *moringa* together with a mixture of range species (50:50), the third a mixture of range species alone.

Within the agroforestry model, the highest yields were obtained in 2014 by *Dactyloctnium aegyptium* (90 t ha^{-1}), followed by *Farsetia longisiliqua* (21 t ha^{-1}), then *Lasiurus scindicus* (14 t ha^{-1}), *Clitoria ternatae* (7 t ha^{-1}) and finally *Alysicerpus monilifer* (2.1 t ha^{-1}). During the year 2015, the highest yield was obtained by *Lasiurus scindicus* (248 t ha^{-1}) followed by *Clitoria ternatae* (289 t ha^{-1}), then *Dactyloctnium aegyptium* (92 t ha^{-1}) then *Alysicerpus monilifer* (91 t ha^{-1}) and *Farsetia longisiliqua* (90 t ha^{-1}). For both control and agroforestry treatments, year effect was significant ($P \leq 0.001$) where year 2015 gave better yields.

Crude protein and dry matter contents increased in post-compared to pre-flowering whereas ether extract and ash content decreased with post-flowering for all plant species. Soil anaylsis showed significant improvement after plantation as compared to before, however, soil salinity and phosphours was significantly ($P \leq 0.01$) reduced due to plantation. The mean gain in body weight was the highest (7.1 kg) for rams given the mixture of range species and *moringa*followed by those given range species alone (4.7 kg) and those given *moringa*alone (3.3 kg), the differences were significant (($P \leq 0.05$). However, the feed conversion ratio was better for rams fed *moringa* alone (0.039), then those fed range species alone (0.044), then those fed *moringa* plus range species (0.082). It could be conculded that agroferstry could improve both range condition and animal preformance.

Keywords: Agroforestry, animals' performance, rangelands

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Assessment of phytodiversity in organic agricultural landscape of central Ukraine

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Biotopes such as ecotones, forest shelter belts (FSBs) and fields are marginal habitats in the agricultural landscape. However, despite their small size, they are repositories of natural vegetation and species-rich animal groups. They are especially important in areas where the intensification of agricultural work reduces the ecological quality of the landscape. They support biodiversity, help maintain the sustainability of surrounding agro-ecosystems and provide them with important ecosystem services (pollinator services, habitat conservation and biodiversity, etc.), as a barrier to pollution and ecological corridors, and support life cycles, food chains and energy transmission in ecosystems, etc.

Our study was conducted on organic agricultural lands (Skvyra, Kyiv region; Ukraine) from 2019 to 2021. Organic crops along the perimeter of the field with an area of 40 hectares are protected by four FSBs of different assessment and sanitary characteristics.

We studied the dynamics of biodiversity in the organic agro-landscape in three types of habitats according to the gradient of anthropogenic impact – segetal (fields, n = 6), ruderal (ecotones, n = 14; on wheat, oats, soybeans, milk thistle crops), FSBs (n = 4). As a result of data analysis, 128 higher plants belonging to three divisions, 4 classes of 45 families, 85 genera were identified in ecotones and fields of organic crops in 3 years. In FSB 92 species, in ecotones 113 species, in fields 52 species were found. Field weeds occur in ecotones – 38 species (29.7 %), in the field – 29 species 24.7 % of identified species.

For Shannon's indice, biodiversity decreases from FSBs through ecotones to fields, this is explained by the transformative impact of humans in monoculture fields. The high biodiversity rate in ecotones and the highest in FSB indicate the ability of these habitats to perform biodiversity preservation ecosystem services.

Keywords: Biodiversity, ecotones, forest shelter belts, habitats, organic agriculture

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Empirical analysis of fuelwood consumptions and its environmentafl implications in rural sub-city, southern Ethiopia

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With the predicted fast growth of the human population and economic development, the global energy demand is expected to be high in the coming decades. In Ethiopia, traditional biomass fuels (animal dung, crop residues, fuelwood and charcoal) are the primary source of domestic energy for the majority of the rural population. The use of fuelwood as an energy source contributes to deforestation that aggravates soil degradation, resulting in soil fertility decline and loss of biodiversity. The consumption of animal dung and crop residues resulted in soil fertility loss and reduced agricultural productivity. Moreover, fuelwood consumption contributes to forest degradation and greenhouse gas emissions. The present study aimed to assess household energy sources and their contribution to climate change. The multi-stage sampling procedure was employed to select sample households. A total of 152 households with different wealth statuses were included in the present investigation. Firewood consumption and greenhouse gas emission at the household level were estimated. The average annual firewood consumption per household was 2781.30 kg (2.78 tons). The amount of firewood consumed per household could emit 337.62 kg CO_2 eq yr^{-1}. The use of an improved stove could help to save 1.05 tons of firewood and protect 4×10^{-3} ha of forest degradation per year per household. Improved energy saving stoves were observed to reduce the amount of firewood consumption at the household level and resultantly reduced forest degradation and greenhouse gas emissions. Therefore, all stakeholders in the household energy sector need to work jointly in awareness creation and provision of alternative energy sources and improved energy-saving technologies.

Keywords: Energy source, environmental impacts, fuelwood, household, stove

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Can home gardens feed the world? The role of home gardens in urban food security and livelihoods in Ghana

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Cities around the world are faced with severe challenges that make life difficult for the growing population. These challenges include climate change, food shortage and urban heat island effect. Home gardens have been suggested as one of the tools that can help cities adapt to these challenges. Despite its benefits the academic literature on home gardens is surprisingly small. At the same time learning from other countries and the adoption of best tree species and food cropping practices are often limited. This study hopes to bridge this knowledge gap. The objectives of the study are 1) To identify the types of trees species and food crops suitable and preferred for planting in home gardens; 2) To assess whether these trees and food crops make any significant contribution to household income and food security and, 3) To identify the factors affecting the sustainability of home gardens in urban landscape. A mixed method approach in a case study research design was adopted for the study. The study established that, there were diverse tree crops preferred by households for planting in home gardens; these include: cocoa, orange, neem tree, mango, avocado, moringa, teak, cedrela, oil palm, coconut, pawpaw, cashew, guava and Indian almond. The food crops preferred include: tomatoes, garden eggs, pineapple, plantain, cassava, cocoyam, maize, okra, banana, watermelon, legumes and yam. These trees and food crops were found to contribute immensely to household income and food needs. However, several factors affected the sustainability of home gardens in urban areas, these include destruction of gardens by stray animals, pest and disease attack, vandalism and low soil nutrient. Recommendations include fencing of home gardens to curtail stray animals and vandalism, mulching to improve soil nutrients and fertility, and provision of pesticides to control pest and diseases.

Keywords: Food security and livelihoods, home gardens

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Palm fruit's potential for sustainable commercialisation in Pando, Bolivia

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Palm fruits are important non-timber forest products (NTFP) for the livelihoods of rural people in the Amazon region, as many are nutritious foods and have the potential to generate income. However, the conditions for their commercialisation are in many cases underdeveloped. The aim of this study was to assess the potential of four palm fruits for sustainable commercialisation in two different rural communities in Pando, Bolivia: inside and outside of a national reserve. The palm fruits studied were Asai (*Euterpe precatoria* Mart), Majo (*Oenocarpus bataua* Mart), Motacu (*Attalea phalerata* Mart. ex Spreng) and Palma real (*Mauritia flexuosa* L.f.). We gathered data from 14 key informants, using semi-structured online interviews, and 20 community members, using structured interviews. We analysed the data with qualitative content and multi-criteria analyses. Asai was the palm fruit with the highest commercialisation potential due to its high abundance, high demand and targeted institutional support, among others. Second was Majo, which benefited from its similarities with Asai regarding harvesting and processing, but technical processing deficiencies limited its commercialisation. Palma real and Motacu had medium and low potentials because of a lack of knowledge regarding their harvesting and processing and low consumption. The community inside the national reserve had higher potential for palm fruit commercialisation than the community outside, which was due to institutional support for the development of NTFP commercialisation in protected areas. This study demonstrates the importance of considering varied multidisciplinary factors and their interrelations for sustainable commercialisation of NTFP. Furthermore, it served to identify the factors that need further promotion and implementation for each palm fruit studied.

Keywords: Economic income, markets, non-wood forest products, NFTP, rural producers, sustainable harvesting, value chains, wild fruits

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Ecological sustainability of cocoa production: role of traditional agroforestry systems on biodiversity conservation and ecosystem services in Cote d'Ivoire

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In Côte d'Ivoire, as in all West Africa, the cocoa farms from forest conversion result in drastic decline of forest vegetation and its biodiversity. Facing this unendurable situation, agroforestry systems (AF), such as the smallholders' plantations where trees have long been maintained and associated for diverse purposes can offer promising sustainable alternative. But what is the ecological sustainability of the traditional agroforestry systems in Côte d'Ivoire and what are their role on biodiversity conservation, ecosystem services? In addition to the goods and services provided by the associated species, only local farmers' perceptions on these species and systems seem to be able to allow their maintenance and the success of this cultivation system. To address these questions, a study had been carried out in the Centre of the country to analyse the practices through a survey of one hundred and five peasants in which we recorded their utilisation of plant species in cocoa plantations and their perceptions. We also inventoried the diversity of plant species in 105 plots of 625 m^2 each and the services that can be benefited from these traditional AF focusing on provisioning services. We analysed how the tree species contribute to biodiversity conservation (a special focus on the species with high conservation value). Then the biomass and the carbon stock of the associated trees had been computed. The results showed that 65 species were recognised by farmers as being compatible or not with the cocoa cultivation. Large trees like Milicia excelsa that would maintain soil fertility or moisture in the environment, were marked favourable to cocoa. The majority of food species had no known effect on cocoa trees. The study showed that most of species are associated with cocoa trees to provide food and medicinal goods to local people. Tree biomass and rates of carbon sequestrated were important. The farms housed high conservation value species. The study suggested the agroforestry systems in the Centre provide important ecosystem services as well as biodiversity conservation.

Keywords: Biodiversity conservation, Côte d'Ivoire, ecosystem services, farming practices, perceptions, shade species

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Consumers and food

Pathways to improved food and nutrition security

Characterisation of the rural food environment in Lindi-Tanzania and its influence on nutritional security

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There have been increased cases of triple burden of malnutrition which has heightened the food security situation in many developing countries, especially, in sub–Saharan Africa. This is partly, attributed to changing food environment in low-income countries. The food environment is the availability, affordability, convenience, and desirability of various foods. Our aim is to, determine how the food environment can be transformed to promote the uptake of nutrient-dense diets in rural households using a case study of the Lindi Region of Tanzania. We begin by characterising the rural food environment, we then analyse the relationship between the food environment elements and household dietary patterns to inform possible interventions that enhance nutrient-dense dietary consumption. We use qualitative methods, to define the food environment based on food accessibility and availability measures. We conducted 7 focus group discussions made of 10 participants each, randomly selected from each of the villages. Additionally, we did 5 expert interviews with the District Nutritional and Agricultural officers. The data were transcribed, coded, and analysed through framework analysis using the MAXQDA® qualitative data analysis tool. The results indicate that the main source of food in the community is from own production that, employs traditional farming methods. The yields are, therefore, not sufficient to sustain adequate dietary requirements till the next harvest season. Additionally, because of poverty, occasioned by financial illiteracy, and distance to the nearest market there is difficulty in accessing food from the informal and formal markets of the built food environment. Resultantly, there exists a continuous "hungry gap" between harvests. The government policies are mainly towards the production and marketing of cashew nuts which is the main cash crop at the expense of food crops. Interestingly, the wild food environment is still pronounced and is a major source of proteins, leafy vegetables, and fruits, especially during the lean seasons. The government needs to step up interventions to encourage the intercropping of cash crops with locally adopted legumes like pigeon peas, traditional vegetables, and fruits. Equally, important intervention would be financial literacy to enable economic access to food.

Keywords: Food accessibility, food availability, hungry gap, nutrient-dense

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Food access and dietary diversity in subsistence farming contexts: Farm production and markets in Burundi

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Consumption of diversified foods guarantee diet quality and combat malnutrition in all its forms. Dietary diversity is important as a pathway that can alleviate food and nutrition insecurity. The interest in setting out this analysis was based on understanding the relationship between food access and dietary diversity in a context of subsistence farming of rural small-scale households, starting from the farm agricultural production diversity. This linkage between farm production diversity and individual dietary diversity remains unclear. By means of a survey study, this paper analyses this relationship, especially for women of childbearing age and children under 5 years.

The study covered two provinces in Burundi: Muyinga and Ngozi, accounting for 233 and 350 households respectively. For the children's Dietary Diversity Score (DDS_C), data have been collected on 258 children under 5 years old, while 424 women have been surveyed. For both women and children, a 24-hour recall was used to assess the DDS. The level of diversification of the diet was generally low in the study area. Results showed a low diversity of diet for both women of childbearing age and children under 5 years old. For the women, the average number of food groups consumed during the 24 hours preceding the survey time were 4.64 and 4.34 respectively from Muyinga and Ngozi. As for the children under five years old, the average number of food groups consumed were 3.07 and 3.14 in Muyinga and Ngozi respectively. The recommended number of food group per individual is at least 5 and 4 food groups for women of childbearing age and children under 5 years-old respectively. Yet, rural farmers in the region produce mainly for food self-sufficiency, some of them get extra-farm income which can contribute to accessing food. Contrary to other similar studies, some agricultural production diversity indicators were not shown to be significantly associated with both the minimum dietary diversity for women (MDD_W) and the dietary diversity score for children (DDS_C). The off-farm income was significantly associated with both MDD_W and DDS_C. In a subsistence farming system context, the market plays an important role in dietary diversity.

Keywords: Market, nutrition quality, off-farm income

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Seasonality, food safety and dietary diversity in urban Ghana

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Urban households depend on food markets for majority of their food needs and the number of urban dwellers is growing rapidly in developing countries. However, urban food markets are significantly dependent on domestic food production and supply chains in most developing countries. Thus, urban food markets are prone to risks of weather seasonality. In Ghana, food production is mainly rainfall dependent. Seasonality does not only affect household food accessibility, availability, utilisation and stability, but potentially also household food safety through interactions with hygiene/ sanitation and the (open) market place and the household. Using a two-round panel household data, fixed effects Poisson and correlated random effects (CRE) Probit models, we estimate the effect of seasonality on urban household dietary diversity, food expenditure and food safety. Household data was collected from communities in three major cities in the southern, middle and northern parts of Ghana. Same households were surveyed in both rounds and there were about 600 households in each round. Our results show that although household dietary diversity score (HDDS) and food expenditure per capita was lower and higher respectively in the dry (harvest) season, we did not find the effect of seasonality on HDDS and food expenditure per capita to be statistically significant among sampled urban households. The end of the harvest season is generally characterised by higher food availability and lower food prices of mostly cereals and starchy staples. The dry season does not coincide with the availability of fresh fruits and green leafy vegetables which are relatively more expensive during this period. The results also show that, the incidence of diarrhoea/vomiting as a measure of household food safety is higher in the dry season. The higher incidence of diarrhoea/vomiting in the dry season may be linked to the change in the water, sanitation and hygiene (WASH) behaviour of households potentially because of inconsistent water supply to households especially in the dry season. Wealthier households recorded lower incidence of diarrhoea/vomiting. We recommend to consider seasonality of urban food consumption in agriculture policy and in particular in value chain management, considering the potential cultural preferences for seasonal diets in order to improve urban food and nutrition security.

Keywords: Dietary diversity, food safety, open markets, seasonality, urban

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Does urban farming increase access to diversified diets? A case study from urban households in Kampala, Uganda

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Little is known about the effect of urban agriculture on the access to a variety of foods in low and middle-class urban households. As Africa is urbanizing rapidly, poverty and malnutrition hotspots are moving from rural to urban communities. This goes hand in hand with an increase in the consumption of unhealthy food. Especially cities are faced with the triple burden of malnutrition. Urban agriculture could play an important role not only to increase access to food but also in increasing the variety and diversity of current consumption patterns. Especially perishable products like vegetables can be easily produced in urban areas. Thus, this paper aims to identify if households that are involved in and or have access to urban agriculture have a more diversified diet. The study was conducted in the Kanyanya parish in Kawempa division in Kampala (Uganda). Kanyanya is a densely populated area with 28,000 inhabitants, mainly low and middle-income consumers. A survey among 450 households was conducted asking questions about urban farming and household food consumption over the past week. Dietary consumption and food variety was assessed through a 7-day food consumption recall to calculate different dietary diversity indicators, such as the household dietary diversity score (HDDS). The research was conducted in the context of the Nouricity project, aiming to improve rural livelihoods and food and nutrition security in several African countries by addressing challenges that prevent access to healthy diets and nutrition in urban African food systems and identifying effective interventions jointly with local stakeholders. Preliminary results confirm the positive effects of urban agriculture at the household level with a high HDDS.

Keywords: Diets, household dietary diversity, Uganda, urban farming

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Effect of non-participation of local/indigenous people in the development and implementation of child feeding programs

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Local knowledge is a huge, largely untapped, resource that can be applied to influence highly adaptable child feeding practices. In Kenya, community health volunteers and mothers form important linkage through which local and indigenous knowledge can be tapped for adaptation of interventions to improve child feeding practices. This paper examines extend and how community health volunteers and mothers have been involved in development and implementation of currently used communication strategies and materials on child feeding practices. This study was conducted between July – December 2021 in Marsabit County in Kenya, largely rural pastoral community with some emerging urban communities that tended towards urban lives. This was a qualitative study with 101 participants comprising 52 mothers, 49 community health volunteers through 10 focus group discussions. Mothers and community health volunteers were individuals from the community with experience of local context regarding child feeding practices and associated challenges. The study found that out of the more than five major programs implemented in the county on child feeding practices in the last five years, participation of indigenous people (mothers and community health volunteers) remained nonexistent. However, during implementation all programs brought in participation of community health volunteers through training on capacities for adoption and sustainability of the practices by mothers and caregivers of children who participated mainly as beneficiaries. Further, findings show that almost all programs on child feeding practices experienced challenges at implementation with difficulties in accessing types of food promoted due to seasonality of crops and the migration life style of pastoralists with very low demonstrated sustainability especially among the rural pastoralists. Findings of this study highlight consequences of non-integration of local and indigenous knowledge in the design and implementation of child feeding practices that include high level of challenges in implementation, lack of adaptation to local context and ultimately unsustainable child feeding practices.

Keywords: Child feeding practice, local knowledge, local/indigenous people

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Smallholder farmers' food production and dietary diversification: a qualitative study in Lindi, rural Tanzania

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Improving small holder farmers' ability to produce a diverse range of foods has been identified as a significant technique for increasing food and nutritional diversity. In Tanzania, nevertheless, there is little evidence linking household production to dietary diversification. The extent to which farm output diversity is connected with dietary diversity is investigated in this study, which uses cross sectional data of 440 households in two semi-arid villages in Lindi region in Tanzania. The results revealed a moderate level of dietary diversity in households. The farm households majorly produced four food groups (pulses, meat, grains, and vegetables), indicating that food purchases were more common than household production. Households that use more money on foods were more likely to eat a more diversified diet compared to those with lower spending on food, implying that market integration is linked to greater dietary diversity. Results indicated that farming households consumed 4 out of 12 food groups on average with very low consumption of fruits and vegetables. Dietary diversity varied by demographics and socioeconomic characteristics of households. There was a positive association between own production diversification and dietary diversity. However, there was no link between production diversity and intake of micronutrient-rich foods like fruits and vegetables. It was indicated further that the disadvantaged households with a better income preferred to have tastier foods that diversified ones. Some of the primary drivers of dietary diversity among subsistence households were higher levels of education, per capita income, food spending, and geographic location. The results suggest that inspiring disadvantaged households in Tanzania to grow a variety of food and animal species could be an operative technique for improving nutritional diversity.

Keywords: Dietary diversity, household own production, smallholder farmers

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Assessment of food control system: a narrative review

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Food is one of the primary human needs, and its safety needs to be maintained. In low-income and middle-income countries, food consumption is the most significant consumption compared to other categories. Food safety has an impact on public health and affects the economy through product competitiveness. Therefore, it is necessary to support a good national food control system to maintain food safety. Assessment of the food control system is a must. Food and Agriculture Organisation (FAO) and World Health Organisation (WHO) have issued guidelines for assessing national food control systems. This study examines the results of assessments of national food control systems in various countries and compares them with FAO and WHO guidelines. The method used is a narrative review. The author collected seven electronic databases, from 2010–2020.

From the results of article searches and eligibility checks, 26 full-text articles were obtained. Food control systems in various countries have their uniqueness, regarding single agency, multiple agencies, and integrated systems. This depends on the breadth and complexity of the food control system as a reflection of the governance of their countries and influenced the delegation of authority to the control agency. However, it can be concluded that the elements used in the assessment of the national food control system are generally uniform, which include regulatory needs, infrastructure, budget, human resources, and a solid coordination network, especially for countries that implement a multi-agency control system, implement control functions, and implement sustainable risk analysis. This element is in line with FAO and WHO assessment guidelines. The new and positive things in assessing the food control system are the importance of assessing the interaction between stakeholders and risk analysis. Both of these strengthen the foundation of the system's assessment.

There are variations in the food control systems, but universal things that determine the success of implementing a food control system are clarity and appropriateness of regulation and coordination. Synchronisation and harmonisation of regulations and the interaction between stakeholders are the lessons learned to improve the food control system, which will determine the safety of world food consumption.

Keywords: Coordination, food consumption, food safety, regulation

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One Health: Epidemiology of antimicrobial resistance in children, food and livestock in a low-income setting

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In developing countries, foodborne disease (FBD) is a threat to human health with children under 2 years being particularly vulnerable. As from 6 months on, they begin to consume weaning foods and water that may be contaminated. This often causes diarrhea, the second leading cause of infant mortality after pneumonia. Bacteria such as *Escherichia coli* and *Salmonella* spp. have been identified in FBD as the major causes of illness and death in children, often requiring therapeutic interventions.
Inappropriate use of antimicrobials for humans and animals, inadequate water, sanitation and hygiene, and poor infection control in hospitals and clinics may influence antimicrobial resistance (AMR) in these pathogens, and transfer between people, animals and the environment. AMR is one of the biggest threats to global health, food security and development. Globally, 700,000 deaths are attributable to drug-resistant infections every year with low-income countries being the most affected. Increasing rates of AMR will limit therapeutic options.
In this study, we isolated and identified *E. coli* pathotypes and *Salmonella* spp. from stool collected from 541 children (6–24 months), 296 livestock, and 860 food samples (from farm-to-fork) from a low-income peri-urban setting in Nairobi, Kenya. We are currently pathotyping isolates and testing for their sensitivity to commonly used/prescribed antibiotics and profiling their resistome by polymerase chain reaction (PCR) and whole genome sequencing (WGS). Results will be used to determine the phylogeny and virulome amongst epidemiologically related isolates to understand spread and pathogenic potential and the burden of AMR in children. This project will provide valuable data on strain diversity and circulating *Salmonella* and *E. coli* clones in Kenya. Information on AMR in childhood diarrheal infections will contribute to AMR surveillance in Kenya and inform treatment guidelines. Further, detected AMR reservoirs in food and in contact animals may help evaluate risks to children, information that can be used to design interventions.

Keywords: Antimicrobial resistance, diarrhea, food-borne disease

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We need to go back to the time of our grandparents: Perceptions of health and environmental aspects within a rapidly changing food landscape – findings from a qualitative study conducted in urban Burkina Faso

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Objective: To explore the perceptions of health and environmental aspects associated with current and former dietary habits in urban Burkina Faso.
Design: Exploratory qualitative study using purposeful maximum variation sampling. Conduct of semi-structured face-to-face interviews in Morré and French which were audio-recorded, translated into French, and transcribed verbatim. Data were analysed inductively, using thematic analysis.
Setting: Three informal and two formal neighbourhoods within the consisted area of the Health and Demographic Surveillance System (HDSS) Ouagadougou, Burkina Faso, February – March 2021
Participants: A total of 36 participants aged 25–73 years were interviewed. 18 males (9 formal, 9 informal) and 18 females (8 formal, 10 informal) were surveyed.
Results: The main characteristics that participants associated with a healthy and eco-friendly diet were traditional, local, natural, pure, organic, and transparent ways of producing, processing, and preparing food. However, several perceived barriers complicate to follow these ideals. Importantly, limited financial resources were described to narrow dietary choices, as satisfying hunger often has highest priority. Other experienced barriers were related to availability of products, limited time, compromising food choices within the family, and lack of knowledge about the relations between nutrition, health, and the environment. Most of these barriers were related to experienced transitions regarding the food system, lifestyle, and climate.
Conclusions: To reduce the described barriers, public health interventions need to target different levels, synergistically addressing knowledge promotion and consolidation of believes in traditional diets as healthy and eco-friendly. Furthermore, political action is needed to reduce financial barriers, enhance public health, and make the local food system more resilient to climate change.

Keywords: Burkina Faso, healthy and sustainable nutrition, Ouagadougou, qualitative study

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Food environment of children under five in dryland areas of northern Benin

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Food environments play a major role in children's diets and nutrition, as they determine household access and supply of nutritious food. Research on food environments to date in low-income countries is limited; the outcome is a lack of data on the food environments of the African drylands. The objective of this study is to characterize the current food environment of children under five in the dry areas of northern Benin. To do this, twelve group discussions with local nutrition actors, eight individual interviews with key informants with visits and examinations of products in stores, local markets and domestic stalls were conducted in eleven villages and city districts in the municipalities of Banikoara and Nikki in northern Benin. Descriptive statistics were used to describe the dimensions of the food environment using SPSS software (v. 21). The results obtained show this: (i-availability and accessibility) the presence of a hundred foods (94) of which 38 % come from harvesting and/or picking (concerns the diet of the most large part of the population) and 89 % are sold in local markets and domestic stalls. 22 % of food is seasonal and 78 % is available all year round. (ii-price and affordability) for food sold, 79 % of them is sold in affordable format with prices between X0F 25–200, less than X0F 244 (which is the maximum capacity of daily food expenditure of people in the study area). (iii-food property and convenience) foods sold in bulk (72 %) with only 23 % being packaged (90 % of which are labeled and contain nutritional information). Processed foods are few (19%) leaving room for traditional cuisine. (iv-marketing, regulation and desirability) customary foods with eight out of ten foods originating from the region. The desirability of food comes from eating habits. This food environment can be considered as the natural type with the coexistence of the informal market type.The supply of nutritious, affordable convenience and desirable foods is subject to the variability and seasonality of local agricultural products and food resources.

Keywords: Benin, child malnutrition, dryland areas, food environment

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Are vegetables or fruits out of reach in Turkana county, Kenya?

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Background: The food environment as an element of food systems, is the context in which people select, acquire, prepare, and consume food. Food environment is thus a determinant of diet quality and nutritional outcomes because people mainly consume what is within their physical and economic reach.
Method: In ten randomly selected Community Units in Turkana (semi-arid/ arid), informal and formal food vendors were geocoded and mapped using the produce-colour-diversity tool. It generates a score (max=6) counting the number of "colours" of fruits and vegetables sold by the vendors to get a general understanding of the antioxidants and micronutrients present, which are associated with colour. Twenty households were selected based on their apparent knowledge of the community's food environment for in-depth interviews.
Results: Out of the 384 geocoded vendors in the food and drink sectors only 44 % offered fruits and vegetables. Most of them were retailers or kiosk type vendors (39 %), followed by roadside vendors (30 %), restaurants (12 %), mobile vendors (8 %), open-air-markets (4 %), street hawkers (4 %) and supermarkets (2 %). In general, rural areas recorded fewer vendors in all categories. Roadside vendors and supermarkets were more likely to offer a wide range of fruits and vegetables with a colour-tool-diversity-score (CTDS) of 3.8 and 4, respectively. Most of the roadside vendors were female vendors (92 %). They showed a lower variety in rural areas compared to Lodwar town which was the preferred marketplace to go to because of its diversity at affordable prices. The perceived distance to the preferred marketplace (most frequently visited by members of the household to purchase food) ranged from 16 up to 210 minutes.
Conclusion: Without access to vegetables and fruits a diverse diet is not possible which is associated with a high risk for malnutrition. In the study area vegetable and fruit production is limited due to water scarcity. At the same time the poverty level in Turkana is high and associated with high levels of food insecurity. The limited opportunities to purchase vegetables and fruits in the surveyed region calls for public health measures to enhance the market availability of fruits and vegetables at affordable prices.

Keywords: Dietary diversity, food security, fruits and vegetables, Kenya, Turkana

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Positive deviance approach in improving child health outcomes: a participatory assessment of child feeding practices in Marsabit county, Kenya

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In order to sustain the gains made by promoting exclusive breastfeeding(EBF) for the first 6 months of life, interventions need to extend into the second half of infancy and beyond. In Marsabit County, EBF rates are high yet malnutrition rates among the under- fives still remains high. This has been attributed to challenges in complementary feeding. Nutrition and health outcomes depend on the level of nutrients consumption found in daily food intake. High quality dish results in good health whereas a poor quality diet results in health deficits. It is the role of mothers or caregivers to ensure provision of adequate diet to the child for positive health outcomes. Thus, this study aimed at determining the positive deviant child feeding practices through participatory assessment in Marsabit, Kenya, in order to promote introduction of nutrient dense complementary feeds and other positive deviant child feeding practices in the region.

Data was gathered from consenting mothers and caregivers of children aged 6 to 24 months, in 9 Focus Group Discussions(FGD) consisting of 10–12 mothers each. Child food samples for nutrient content determination were also collected after completion of each FGD session. Resulting data from the FGDs was categorised into four major themes. These include: Knowledge and perception of the mothers and the caregivers on quality of child feeds, medicinal foods, positive deviant child feeding practices, and the nutrient contents of child feeds in Marsabit County. This study showed that indigenous local knowledge is input into the feeding of children, however, the mothers still expressed their concern on knowledge gap on matters of child feeding. Medicinal foods in the community are also varied and are used for either prevention or treatment purposes.

In the next steps, knowledge exchange and creation sessions amongst the mothers will be conducted on positive deviant child feeding practices and nutrient value of child feeds.

Keywords: Child feeding, health, maternal knowledge, medicinal foods, positive deviance

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Leveraging scaling up of biofortification through small and medium enterprises in Uganda: what are the governance challenges?

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One of the world's challenges is hidden hunger, where 17 % of the global population has an inadequate micronutrients intake. Scaling biofortified crops so that many farmers can grow and consume them is one approach to reducing hidden hunger. Many institutions are involved in scaling biofortified crops, yet governance challenges are not extensively studied to provide policy direction.

This study aimed to identify the governance challenges facing farmers, aggregators, processors, and retailers as one of the scaling pathways and understand whether training may reduce identification governance challenges in high iron beans.

The paper develops a conceptual framework based on new institutional economics to identify the causes of the governance obstacles. We used the process net-map to elicit knowledge regarding processes, actors, and challenges in the food value chain of biofortified crops. The process net map involves the identification of actors, roles the different actors play, their influence on the outcome and challenges in the processes. We used a field lab experiment to determine ways of reducing the identification challenge in the high iron beans. We used correlated random effects models to analyse the effect of training on identifying high iron beans.

The results demonstrate that apart from the known agricultural marketing challenges, vine multipliers are faced with bribery in the supply of vines, and households face a trade-off between allocating land for orange-fleshed potatoes and other varieties. In addition, the value chain actors mix high iron beans with other varieties while consumers are not willing to pay a premium price for biofortified crop products. These challenges result from information asymmetry, nutrition advice merit goods, collective action, and free-riding. Though training can improve the identification of high iron beans, its effect is not significant.

The findings show the existence of gross governance challenges in the biofortified crop food value chain and suggest investment in subsidies to increase production while creating awareness of the importance of nutritious products.

Keywords: Biofortified crops, training, governance challenges, scaling, transaction costs

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Herbal medicine use and perspectives in the context of COVID-19 among the Congolese community in Belgium

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As a hard-hit area during the COVID-19 pandemic, Belgium knew the highest mortality among people from sub-Saharan African descent, compared to any other group living in the country. After migration, people often maintain traditional perceptions and habits regarding health and healthcare, resulting in a high prevalence of traditional, complementary and alternative medicine use among different migrant communities in northern urban settings. Despite being the largest community of sub-Saharan African descent in Belgium, little is known on ethnobotanical practices of the Belgian Congolese community. We therefore conducted an exploratory study on the use of medicinal plants in the context of COVID-19 and perceptions on this new disease among members of the Congolese community in Belgium. We conducted 16 in-depth semi-structured interviews with people of Congolese descent currently living in Belgium. Participants were selected using purposive sampling. Medicinal plant use in the context of COVID-19 was recorded through free-listing. Data on narratives, ideas and perceptions on the origin, cause/aaetiology and overall measures against COVID-19 (including vaccination) were collected. Interview transcripts were analysed using thematic analysis. Four overarching themes emerged from our data. Firstly, participants perceived the representation of the severity of COVID-19 by the Belgian media and government—and by extend by all governmental agencies in the global north—as exaggerated. As a result, traditional and complementary treatments were seen as feasible options to treat symptoms of the disease. Fifteen forms of traditional, complementary and alternative medicine were documented, of which thirteen were plants. Participants seem to fold back on their Congolese identity and traditional knowledge in seeking coping strategies to deal with the COVID-19 pandemic. Finally, institutional postcolonial distrust did not only seem to lead to distrust in official messages on the COVID-19 pandemic but also to feelings of vaccination hesitancy. In the context of the COVID-19 pandemic, participants in our study retreated to, reshaped and adapted traditional and culture-bound knowledge. This study suggests that the fragile and sensitive relationship between sub-Saharan African migrant groups and other social/ethnic groups in Belgium might play a role in their sensitivity to health-threatening situations, such as the COVID-19 pandemic.

Keywords: Belgium, Congolese community, COVID-19, urban ethnobotany

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COVID-19 and household food waste in Colombia: the effects of the strict lockdown in 2020

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Household food waste represents one of the main challenges for sustainable development as it directly affects the economy of food consumers, the loss of natural resources, and generates additional greenhouse gas emissions. The COVID-19 pandemic caused one of the most serious economic crises in recent decades and could become the worst economic crisis that Latin America has had in its history. The objective of this study is to analyse changes in food waste behaviour during the COVID-19 lockdown in Colombia, applying the Theory of planned behaviour (TPB). For this purpose, we conducted a virtual survey with 581 Colombian food consumers from the four major cities (Bogotá, Medellín, Cali, and Barranquilla), which examined the influence of intentions to not waste food, subjective norms, some situational predictors, questions related to the COVID-19 pandemic, and the control of perceived behaviour on food waste. The results suggest that the TPB can predict the intention to not waste food and, through it, the actual household food waste behaviour, considering the lockdown in Colombia as an external shock. We observe that regarding the intention to not waste food, the most relevant variables are attitudes, subjective norms, control of the perceived behaviour, and concerns regarding the COVID-19 pandemic. These variables increase the probability on average by a 0.8 odds ratio that the intention not to waste food increases, too. Regarding food waste behaviour, whether it is considered ordinal or nominal, we see that the most relevant variables are intention, financial attitudes, and control of perceived behaviour, doubling the probability that food waste behaviour will improve. Although these personal considerations about household food waste are relevant predictors, the differential factor between the willingness to not to waste food and effectively not doing it lies in the economic conditions of the households, highlighting the need for strategies aimed at reducing household food waste that consider the different existing income and food expenditure levels, and, above all, reductions caused by the pandemic. Additionally, fear and concern about COVID-19 are also significant predictors, highlighting the need of accurate communication strategies regarding the pandemic and its impacts on society.

Keywords: Consumer behaviour, COVID-19, food waste, logistic regression, pandemic, random forest

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Shea tree (*Vitellaria paradoxa* c. f. Gaertn) and household food security in northern Cameroon

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Shea (*Vitellaria paradoxa* C. F. Gaertn) is identified among the most widely used indigenous fruit tree in sub-Saharan Africa. The derived products (fruit pulp and butter) are a source of food and income for vulnerable people in areas where the shea tree naturally occurs. However, the contribution of shea butter consumption and commercialisation to food security is not well known in Cameroon. This study aims to examine the relationship between shea butter consumption and commercialisation and household food security in northern Cameroon. Quantitative and qualitative data were collected across four subdivisions purposively selected in the north of Cameroon. A total of 384 households in 12 communities were randomly selected and interviewed using a semi-structured questionnaire, whereas qualitative data through Focus Group Discussion (FGD) and interviews with key informants were held before the surveys for a further understanding of the shea value chain and the role of shea in household livelihood in the study area. The Tobit regression model will be used to analyse the link between the food insecurity score (dependent variable) and socio-economic factors often used in the literature to affect food insecurity. Other variables will be included in the model in order to capture the effect of shea nuts and butter on food security in the study areas. The research findings from this study will help actors involved in the shea value chain to develop policies, strategies and programmes that promote the cultivation of shea trees in agroforestry parklands and increase income through shea commercialisation with a view to enhancing the living standard of shea producers in the North region of Cameroon. This could be a viable pathway contributing to the sustainable development goals(SDG) in the study area.

Keywords: Livelihood strategies, NTFPs, rural households

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Identifying policy-level blockades for healthy food systems in Ethiopia

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Background and Objectives: In Ethiopia, the extent to which national policy and strategies are geared to address these challenges related to health and sustainable food systems was not well studied. Thus, the purpose of this study was to identify policy-level blockades for healthy and sustainable food systems in Ethiopia and examine the commitment of the policy environment for gender equity and social justice.
Methods: Descriptive policy review method was used which represented complex determinants of food systems including consumer factors, food environment, supply chain and external drivers. All relevant strategic documents compatible with the framework were identified by searching FAOLEX and GINA databases. Ultimately, 70 national strategic documents relevant to Health, Food and Nutrition, Agriculture, Multisectoral Development, Social Protection, Trade and Industry sectors were included in the analysis.
Results: Most of the existing policies envisage to increase foreign currency earnings from export of agricultural products. Ethiopia is implementing multiple ad hoc measures for controlling food prices. Yet, most of these decisions are temporary. Health and nutrition policies provide limited attention to diet-related non-communicable diseases (NCDs). The agriculture strategies promote government monopoly. Other major blockades are: lack of strategies to mitigate the impacts of urban encroachment, absence of provisions to promote availability of healthy foods in public facilities, and lack of standalone policies in key sub-systems including food safety, fortification, and urban agriculture. The existing agricultural policies promoted equitable access of women and youth to agricultural resources, technologies and services. Development policies pledged to create decent job opportunities to women and socially disadvantaged groups including youth. Conversely, trade policies lack fiscal and non-fiscal incentives to support socially disadvantaged people including women and provide no directions to assure financial access to women-led small and medium size enterprises. The policies provide no protection to peri-urban farmers being dislodged from their livelihood by the uncontrolled expansion of major cities.
Conclusion: Trade policies should assure reasonable balance between export and import of healthy foods. Health and nutrition policies should adequately address the key risk factors of diet-related NCDs.

Keywords: Ethiopia, food systems, health, nutrition, policy

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Harnessing genetic diversity in wheat to enhance grain nutrition and yield

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Micronutrient malnutrition, especially iron and zinc, affect more than two billion people around the world. Improving these micronutrients content in staple food crops is a straightforward strategy to combat malnutrition through biofortification breeding. However, the genetic improvement of micronutrients depends on the genetic diversity and variability in the primary gene pool. Moreover, to ensure the synergistic effects and trade-offs between grain nutrients, morpho-physiological and yield traits should also be improved simultaneously. Therefore, the present study was conducted to ascertain the magnitude of genetic variability among different *Triticum* species for iron and zinc and standard leaf and seed morphological traits. For this purpose, a diverse germplasm of 813 genotypes including *T. aestivum, durum*, and *Triticale* was screened for grain color. A core collection of twenty-six genotypes was selected for the elemental analysis from a set of sixty genotypes after quantification of grain color. The results indicated high magnitude of diversity for Fe and Zn content ranging from 52 to 113 mg kg^{-1} and 14 to 62 mg kg^{-1}, respectively. Overall, durum had higher mean iron content (80 mg kg^{-1}) while *T. aestivum* had higher average zinc content (34 mg kg^{-1}). High estimates of variability (> 80 %) were observed for Fe, Zn, leaf angle, groove type, and plant height. The lower environmental variance for quality traits indicates strong genetic control supported by strong positive correlation among the micronutrients. The genotypes coded as 87 followed by 309 showed high Fe (94.1 mg kg^{-1}) and Zn (62.2 mg kg^{-1}) along with amber grain color and high grain yield (501 g $plot^{-1}$). Positive associations were found among the micronutrients, amber grain color and yield contributing traits favoring the simultaneous improvement of all these traits. This set of genotypes can be utilised in biofortification breeding programs to elucidate the bioavailability of iron and zinc. Moreover, the strongly positive association between iron and zinc content indicates that similar genes control the pathways for uptake and translocation without having an antagonistic effect and should further be explored.

Keywords: Biofortification, grain colour, iron, malnutrition, zinc

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Understanding complementary feeding practices of child caregivers in northern Benin: a meal culture perspective

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The Benin Demographic and Health Survey recently reported that child malnutrition is an important problem, as stunting is observed in 41 % among children under the age of 5 years in rural poor households. Social and cultural contexts of child feeding gained interest as influencing factors for improving feeding practices and children's health and nutrition. However, little attention has been paid to this aspect in most interventions and there is limited in-depth information on traditional feeding practices. This study aims to understand complementary feeding practices from a food culture perspective. Data were collected from mothers of children under 5 years of age from Fulani and Gando agropastoralist communities with a common Fulfulde language in Yagbo and Simpérou-Peul villages in Banikoara District, North Benin. Participant observation and semi-structured interviews were conducted with 12 mothers using a checklist related to food provision, including cooking, serving and eating meals, and the reasons for these practices. The results showed that the mothers mainly used home-prepared meals for their children's complementary feeding. In the study villages inhabited by Fulani and Gando, we observed that the daily preparation and consumption of food is not only geared towards meeting the needs of their own household, but also the needs of the children of some neighbouring households, including the friends of their child/children's generation. In everyday life, the mother of a child in one household sends her meal to another household on behalf of a child/children, or the children join together in a particular household to eat in groups when the meal is due. Furthermore, social occasions such as baptisms or weddings mobilise child mothers at the extended household or village level to engage in communal cooking activities where they share meals for household, including child feeding. Child feeding practices are thus part of social considerations of solidarity and sense of belonging that affect household food availability, including frequency of child feeding, and food diversity. This exploratory study highlights multiple aspects related to meal sharing scenarios that need to be taken into account and can play a key role in supporting child feeding and nutrition in rural contexts.

Keywords: Benin, caregivers, complementary feeding and nutrition practices, infant and young child, meal cultures

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Thai underutilised fruit and vegetable species as potential sources of antioxidants, minerals and vitamins

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At present, when humanity is still facing persistent malnutrition, diseases of affluence are emerging at the same time. Furthermore, crop production focuses only on a very limited number of species requiring high inputs. The main reason for malnutrition mostly lies in the insufficient consumption of fruits and vegetables. These are irreplaceable sources of biologically active substances such as antioxidants that protect cells against oxidative damage, minerals that play a huge role in various biological processes such as transmitting nerve impulses, and vitamins that serve as antioxidants, coenzymes, cofactors, hormones, and others. Deficiencies of these substances can be fatal in the long run. Often ignored sources of these substances are underutilised crops which have many benefits such as high nutritional value, resistance to biotic stresses, and the ability to strengthen the food security of the country. Thailand is a part of the Indo-Burma biodiversity hotspot, one of the most biodiverse areas in the world, and provides various kinds of fruits and vegetables, including little-explored species. Also, Thai cuisine is rich in local unique ingredients and considered healthy. This review aimed to identify Thai underutilised fruit and vegetable species containing notable amounts of antioxidants, minerals, and vitamins. In this review, 73 underutilised species of Thai fruits and vegetables were found in the scientific literature. The most promising crops in terms of antioxidants seem to be *Durio kutejensis* and *Cosmos caudatus*, in the terms of minerals *Neptunia oleracea* and *Dracontomelon dao*, and in the terms of vitamins, *Aegle marmelos*, *Mangifera odorata*, and *Sesbania grandiflora*. Some species including for example *A. marmelos* or *S. grandiflora* showed valuable contents for all 3 monitored parameters and are therefore appropriate being promote to enrich their diet and increase the biodiversity of cultivated crops, financial incomes, and living standard. Also, such species could be used in industry to produce various food products. For 8 species, no data on antioxidant activity and contents of minerals and vitamins were available and it would be therefore appropriate to focus on their research as they may have nutritional potential.

Keywords: Edible plants, human nutrition, neglected crops

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Optimisation of nutritional and functional qualities of local complementary foods of southern Ethiopia using a customized mixture design

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Commercially produced complementary foods are inaccessible to rural households in Ethiopia despite of disparity in agro ecologies. And this study aimed to optimise the nutritional and functional properties of local complementary foods using flours of the following locally available crops: maize, red kidney bean, ''kocho''/fermented root of false banana (*Ensete ventricosum*), and pumpkin fruit. Ten formulations were generated using a customized mixture design. A five-point hedonic scale was used for the determination of organoleptic properties, and standard methods were used for the analyses of nutritional composition and functional properties. The flours were mixed in the range of 20%–30 % for kocho, 10%–25 % for pumpkin fruit, 10%–40 % for red kidney bean, and 15%–30 % for maize. Optimal nutritional and functional properties were obtained using 33.5 % kocho, 22.5 % maize, 17.5 % pumpkin, and 26.5 % red kidney bean. Optimal values for functional properties were 0.86 g ml^{-1}, 5.94 g ml^{-1}, 4.14 g ml^{-1}, 2.96 g g^{-1}, 5.0 g ml^{-1}, and 1225.3 cP for bulk density, water absorption capacity, oil absorption capacity, swelling capacity, swelling index, and viscosity, respectively. All formulations were within acceptable limits with scores ranging from 3.00 to 4.32 on a scale of 5. The inclusion of 25 % pumpkin fruit flour and other ingredients between 20 % and 30 % increased the pro-vitamin A carotenoid and vitamin E contents of the composite flours. Apart from optimisation, a higher concentration of limiting amino acids was achieved with 40 % kidney beans and 15%–25 % of the other ingredients. The mineral contents improved with increasing pumpkin, kidney bean, and kocho. To sum up, the nutrient quality, energy density, and functional quality of complementary foods can be optimised at a low cost using local ingredients

Keywords: Child nutrition, fortified food, infant, minerals, product optimisation, vitamins

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Ethnobotanical study of wild edible plants used by Meinit ethnic community in Bench-Maji zone, Southwest Ethiopia

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The Meinit community utilised wild edible plants widely for various purposes, mainly as food, household healthcare, and market value. However, the indigenous knowledge associated with the use of plants is significantly degraded by human and climate variability. The study aims to document the traditional knowledge about wild edible plant species (WEPS) pertained by the Meinit community. Ethnobotanical data were collected by semi-structured interviews of the Meinit community in the Bench-Maji Zone from May 2019 to March 2021. A total of 198 study people aged between 18 and 70 years were interviewed. Ethnobotanical information such as plant local name, growth habit, habitat, edible part, mode of consumption, and preparation was collected from the individual household, focus group discussion, and key informant following standard interviewing methods. Voucher specimens were also collected and identified through standard procedure. A total of 66 WEPS were documented from 34 families. The families Asteraceae, Fabaceae, Amaranthaceae, and Moraceae recorded the highest number of species among documented plants. The diversity of WEPS occurred in varied natural habitats, and the more significant number of WEPS existed in cultivated land (33 species), followed by bushy grassland (18 species). Among documented WEPs, herbs growth habits contained the highest number of species. The WEP's were consumed in many forms, such as raw, boiled, fried, and as beverage; boiling was the usual mode of consumption form. Additionally, among the total documented WEPS, 12 species were used as nutraceutical value, and one species contributed to market value. Human activity was a potential threat to WEPS and associated knowledge. High plant diversity existed in the study area, and these plant resources are still utilised mainly for food, medicine, and income generation, which can contribute a significant role in dietary diversity, food security, and health care for rural households. Wild edible plant diversity and their utilisation knowledge are disappearing. Therefore, priority plants domestication, nutritional, phytochemical and toxicological analysis, and conservation practices are recommended.

Keywords: Market value, medicinal use, threat and conservation practice, traditional knowledge, traditional Meinit recipe

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Nexus of seasonality, dietary practice, and nutritional status among children across agro-ecologies in southern Ethiopia

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The disparity in seasonality and agro-ecological zone in food availability and access contribute to poor nutrition and attributes in malnutrition mainly in subsistence agricultural farming communities. However, a limited number of studies considered these dynamics. Thus, the present study aimed to assess the relationship among seasonality, agro-ecology, nutritional status, and infant and young child (6–23 months) feeding practice (IYCF) in rural southern Ethiopia. To this end, two community-based cross-sectional surveys were employed in which 507 children were screened using multi-stage sampling method. On average 74 % of the mothers initiated timely complementary feeding, highest in lowland 81.3 %. Infant diet diversity score (IDDS) improved from post-harvest 14.4 % to wet lean season 16.4 %. Despite the agro-ecological disparity, more than 50 % of the children met minimum meal frequency (MMF). Consumption of pro-vitamin A foods, grains, roots, and tubers, and other fruits and vegetables showed significant differences across seasons (McNemar's test, $p < 0.05$). In contrast, seasonal variation has no association with consumption of either was iron-rich or animal source foods. Similarly prevalence of stunting and wasting significantly different across season (Wilcoxon signed rank test, p <.001.). The highest prevalence in stunting was 44.6 % in midland during wet lean season followed by 36.4 % and 33.9 % in lowland and highland children respectively. On the other hand, the prevalence of wasting was noted almost unwavering during postharvest 7.2 %, 7.1 %, and 7.2 % highland, midland, and lowland respectively, but dropped significantly to 1.2 %, 1.6 %, and nearly zero respectively in the wet lean season.

In the current study the multivariate analysis result revealed low socioeconomic and socio-demographic characteristics, and poor feeding practice, child age, low maternal educational level, timely complementary feeding initiation, access to media, colostrum feeding, low non-monetary wealth, low household annual income contributed to child malnutrition and poor IYCF at ($p < 0.05$). Therefore, to improve the current inadequate IYCF practice and alleviate malnutrition, policy should focus on rural women's employment opportunities, access to media, maternal education, and postnatal care service.

Keywords: Agroecology, dietary practice, seasonality, stunting and child-nutrition

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Social capital effects on food security resilience: Evidence from Kyrgyzstan

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Although there exists a healthy body of literature related to neighbourhood roles for resilience outcomes, there are two main plausible cautions to get robust results. The first one is related to methodological difficulties to measure neighbourhood social environment and resilience itself; therefore, the majority of findings rely on mainly built environment of neighbourhood and related resilience related factors. The second main challenge is the difficulty find a causal relationship between neighbourhood social aspects and resilience. This study aimed to identify causal inferences between social capital and household resilience to food security. Using detailed "Life in Kyrgyzstan" multi-topic panel data, social capital and resilience to food security were estimated. The estimation of social capital was based on participation and trust. Resilience Capacity Index (RCI) was estimated by using resilience Index Measurement and Analysis (RIMA). In addition to RCI, resilience defining pillars such as Income and Food Access (IFA), Access to Basic Services (ABS), Agricultural Practices and Technologies (APT), and Adaptive Capacity (AC) were included as model outcomes. A principal component analysis (PCA) was used to identify determinant factors of social capital, pillars, and resilience itself. For empirical causal relationships, the impact of trust and membership on both resilience pillars and resilience itself was modelled through the use of IV methods for multiple endogenous variables. Findings through models indicate that improved resilience pillars and resilience itself are associated with higher trust and membership values. Therefore, findings indicate that there is a clear message to consider social capital for strengthening household resilience to food security.

Keywords: Food security, instrumental variable, resilience, social capital

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Opportunities for integrating more fruit in smallholder farms and diets in south-eastern Madagascar

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Consumption of fruit is an important element of a healthy diet, as fruits are sources of vitamins, minerals and bioactive plant compounds. In the south-eastern region of Madagascar, fruits are not adequately integrated into smallholder farmers' diets. Favored by the climate, there is significant potential for increasing the cultivation and consumption of fruit by smallholder communities. This study intends to understand the reasons for low fruit consumption and to identify viable entry points for increasing production and consumption of fruit. We purposively selected four villages with relatively high and five villages with relatively low fruit diversity across three districts in south-eastern Madagascar. In 70 in-depth interviews and five focus group discussions, we gained an understanding about local fruit production, consumption, storage and transformation, considering the gender and social norms. The study revealed that fruit cultivation is given low priority by local farmers. The main constraints relate to the lack of technical skills, declining productivity of fruit trees, and the limited opportunities for commercialization. In addition, women-headed households are also handicapped in cultivation of perennial fruit since it requires secure land tenure. Potential opportunities consist in growing short cycle fruit near the homestead, especially fruit with good market potential. Fruit consumption varies in terms of quantity and distribution, with a peak during and shortly after harvest. It is mainly due to the limited storability of fresh fruits, the absence of fruits in the market, or the lack of cash for buying them. Outside the abundance period, most of the com-

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munity relies on the consumption of unripe or wild fruits. Improved storage and preservation of harvested fruit could therefore help to better cover dietary needs. Farmers have experience with traditional solar drying of lychee fruits in particular. Further increasing capacities for safe solar drying of fruit can be an opportunity, but may be challenged by time constraints. Increasing the awareness of the community on the importance of fruit consumption, promoting simple and locally suitable fruit preservation and storage methods, and generating cash returns from fruit sales could help smallholder farmers to prioritize fruits in their farming systems and in their diets.

Keywords: Atsimo Atsinanana region, fruit consumption, fruit production, gender, storage and preservation

Employment opportunities and status of food security across rural-urban interface of Bangalore

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Urbanisation and agriculture is providing employment opportunity to millions of people through industrialisation and commercialisation. It is also helping the households to improve their incomes and living standards. In addition, creating employment opportunity through urbanisation and agriculture also leads to major changes in food consumption pattern and food purchasing behaviour. The study is carried out in the framework of Indo-German collaborative research project 'The Rural-Urban Interface of Bengaluru - A space of Transition in Agriculture, Economics and Society', sub project 'Food Insecurity at different stages of Urbanisation', funded by the Department of Biotechnology (DBT) of the Government of India. The present study focused on how the verity of employment opportunities across rural-urban interface of Bangalore had influence on food security status. Primary data was collected from the north transect of Bengaluru covering 510 respondents. Employment opportunities identified in rural-urban interface of Bangalore are agriculture, agriculture labourer, livestock, off-farm, non-farm and government employment. The major source of employment in rural gradient based on the percentage of employment generation was agriculture sector (33.0 %) followed by non-farm (31.1 %) and livestock (13.4 %) sector. In Transition the major source of employment was observed in non-farm sector (38.1 %) followed by agriculture (22.9 %) and livestock sector (14.1 %). While in urban gradient it was non-farm sector (49.0 %) followed by off-farm (29.2 %) and livestock sector (10.7 %). The percent of food security was more for the households employed in Government sector in all the three gradients, since monthly/annual income generated from public sector was higher than agriculture sector. It is quite interesting to observe that, in all the sectors of employment, the number of food secure households increased from rural to urban gradients, it is a result of increased employment opportunities at urban gradient. In spite of many Government programmes on food security, still there is an existence of food insecurity in the country. Hence in future along with the implementation of food security programmes, creation of off-farm, non-farm and self-owned employment opportunities at the rural area will help to improve the food security status of rural households as like urban households.

Keywords: Agriculture, employment opportunity, food security, rural-urban interface, urbanisation

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Medicinal plants used in metropolitan zone in Saltillo, Coahuila, Mexico

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Medicinal plants are considered those plants that contain active ingredients in any of their organs or tissues when administered in sufficient doses and for a determined period of time to have a healig effect. Around the world there are at least 35,000 species of medicinal plants and it is estimated that at least 80 % of the world's population depends on them for their health. This study is about the uses of the most common medicinal plants and the most frequent affections in the study area, which was the metropolitan area of Saltillo, Coahuila, in the municipalities of Saltillo, Arteaga and Ramos Arizpe. The study was carried out during the months of February and March 2021. Data were obtained from 113 informants (17 men and 96 women, aged 20 to 70 years), using a semi-structured questionnaire divided into two parts: 1) socioeconomic and demographic information (age, sex, level of education, occupation, etc.) and 2) ethnobotanical information (obtaining data about the medicinal plants of the region).
The report of uses obtained was divided into 12 main categories based on the World Health Organisation's International Statistical Classification of Diseases and Health Problems (ICD, 2019). Informants recorded an average of 4.6 plants and 5 uses. According to gender, women recorded 4.9 plants on average, compared to men with 3.1 plants on average. Inhabitants reported using 82 plants for treatment of diseases, belonging to 37 botanical families. The medicinal species with the highest IVU (Use Value Index) were: chamomile (IVU=0.65) and laurel (IVU=0.35). While the most representative families were: Asteraceae (10 species, 125 use reports), Lamiaceae (12 species, 119 RU) and Lauraceae (4 species, 64 RU). The most common forms of preparation were infusion (88.6 %) and poultice (3.68 %).

Keywords: Asteraceae, etnobotanical, medicinal plants, respiratory system

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Women's diets in East Africa: Can they be healthy and sustainable at the same time?

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Our current food systems are unsustainable and drive present diet intake and in turn are affected by diets. Often only one perspective is taken, and diets are seen as either a driver of change in the food system, e.g. through changing consumer demand, or are seen as an outcome of food systems, e.g. through climate change constraints.
Therefore, we applied the World Index for Sustainability and Health (WISH) - recently developed by Trijsburg et al. (2021) - to assess diets for both environmental sustainability and healthiness. Data were collected in the framework of the Fruits and Vegetables for all Seasons (FruVaSe) project – across two seasons in Kenya, Tanzania and Uganda. Four 24-hour recalls, two per season, were conducted with women of reproductive age. Data analysis consisted of 445, 292, and 415 women in Kenya, Tanzania and Uganda, respectively. Food intake quantities were grouped into 13 food groups and converted to the overall WISH index by giving a score between 0 and 10 based on both their environmental sustainability and healthiness.
Only the food groups whole grains, vegetables, unsaturated oils and added sugars were consumed by nearly all women during the last 24 hours (mean intake of two seasons), yet, not to the recommended amount. An increase in consumption to obtain a higher WISH score – and consequently a healthier and environmentally sustainable diet – is suggested for all food groups, except red meat and saturated oils where consumption was within the suggested range. Increase in unsaturated oils consumption is suggested for Tanzania and Uganda, while consumption of added sugars in Uganda needs to be decreased. When only the mean intake of women who consumed a certain food group was considered, the intake of red meat and poultry was above the recommended intake, and hence should be reduced, while the intake of legumes was too low for women in Uganda, and should be increased.
Through the WISH score, we were able to characterise the diets of women in East Africa which still need to be improved to attain environmental sustainability and healthiness at the same time.

Keywords: Healthy diets, sustainable diets

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Development of acid casein enriched, stabilised and thickened yoghurt using *Musa acuminate* (Green banana) and *Ensete ventricosum* (Bulla) flours

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High acid milk contains coagulated milk proteins, which can be used to stabilise and improve the texture of milks. The purpose of the research was to develop and promote fermented milk production technology that used casein derived from high acid milk, stabilisers which included gelatin, corn starch, green banana/matoke (*Musa acuminata*) and bulla (*Ensete ventricosum*) in powder forms. The study included a lab-based experiment aimed at creating stabilised, thickened, and acid casein-enhanced yoghurt samples. The nutritive value of yoghurt samples was determined. The yoghurt samples' rheological qualities were also determined. Sensory quality and consumer acceptability of stabilised, thickened, and acid casein enriched yoghurt were assessed, as well as small-scale milk processors' willingness to adopt the yoghurt. The results of the study indicated that yoghurt having acid casein and the yoghurt including skim milk powder did not differ significantly in terms of protein (5.0±1;5.0±1), carbohydrates (13.5±0.3; 13.8±0.3), or minerals (0.7 0.01; 0.6±0.02). These two yoghurt samples differed in terms of fats (3.3±0.1; 3.0±0.1), moisture (88±1; 85±1), and acidity (1±0.1; 0.7±0.05). In YBA (Yoghurt containing bulla flour and acid casein) and YCA (Yoghurt containing corn starch and acid casein), the acidity value was significantly distinct (0.7±0.05; 0.6±0.05) and lowest. All of the yoghurt samples had the same pH value (4.6± 0.1). The maximum consistency values (8394.39±317.46 g.sec; 8030.25±319.02g.sec) were found in YBAG (Yoghurt containing bulla flour, acid casein and gelatin) and YMAG (Yoghurt containing matoke flour, acid casein and gelatin) respectively. YBAG had the greatest Cohesiveness (-387.09±17.99 g) and Viscosity Index values (-411.14±14.19 g.sec), which were significantly distinct. In Y CONTROL (Yoghurt containing no acid casein or skim milk powder), YB (Yoghurt containing bulla flour), and YBA, whey separation values (9.65±0.02; 9.21±0.03; 9.01±0.01) were significantly distinct and greatest. Overall, the yoghurt samples with bulla and matoke flours were the most liked. Small scale milk processors' (SMEs) willingness to adopt the novel fermented milk product was satisfactory. SMEs and farmers should attend training sessions to improve their knowledge of locally produced value-added dairy products such as the developed yoghurt.

Keywords: Bulla, casein, enset, green banana, high acid milk

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Strategies to reduce food waste – a case study in India avoiding bruises on apples by optimising orchard management

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Reduction of food waste not only helps to reduce greenhouse gas emissions (GHGs) on a global scale, but also incorporates many steps along the supply chain. The review and study is based on several visits on-site which identified potential causes food waste.
Mechanical damage such as bruises of apples (*Malus domestica* Borkh.), which can result in considerable wastage and decline in quality, is a major problem of the apple industry. The extent of the mechanical damage depends on preharvest, harvest, and postharvest management. Bruises are often caused preharvest and only become visible postharvest. This contribution attempts to review bottlenecks of bruise development along the supply chain and identify countermeasures. Improper handling from harvest to retail has a high potential to cause bruises. In India, the fifth-largest apple producer in the world with more than 2 mil t per year, farmers and the apple industry are in a continuous process of reducing losses caused by mechanical damage. This overview explains the formation and development of bruises, followed by the causes of mechanical damage. Opportunities to reduce or avoid bruises along the whole value chain are described with particular regard to the situation in India. This includes pre-harvest management factors such as crop load management, water availability, and nutrient availability as well as the harvest management factors maturity stage, harvest time during the day, harvest method, packing and transport of the apple bins out of the orchard. The final part focuses on postharvest management practices with the themes precooling, hygiene, chemical treatment, grading, storage, packing, loading and unloading, stacking, transport, resorting, and retail.

Keywords: Apple, bruise, consumer, food, food waste, India, orchard management, supply chain

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Potential uses of sago for food diversification and sustainable food system

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Sago is a staple food for people in eastern part of Indonesia. Several decades ago, the Indonesian government began to introduce rice as a substitute staple food, so that the conversion of land into rice fields often occurs in Eastern Indonesia. However, this policy seems less successful and the Indonesian government is again promoting food diversification and diversification to ensure the availability and food security as well the fulfilment of nutrients for the community. The implementation of special autonomy in the eastern part of Indonesia, in particular the provinces of Papua and West Papua, provides flexibility for the regions to determine policies related to the fulfilment of food and energy for their regions. Comparison of the economic benefits and nutritional value of sago and rice provides information on policy recommendations that are beneficial to the region and the community.

In general, the nutritional composition of rice and sago is comparable, the composition of carbohydrates is 80.82 and 84.62 % with a total energy of about 357.46 and 341.45 kcal, respectively. In addition to functioning as food, sago palms can also be used for animal feed, renewable energy sources and fertilisers so as to provide complete and sustainable benefits. As a feed source, sago waste contains a total fiber of about 15.32 % which includes 32.74 % NDF (neutral detergent fiber), 26.22 ADF (acid detergent fiber) and 22.01 ADL (lignin acid detergent fiber). Data of land use that was collected in 2020 shows an estimated area of sago (a combination of natural growing and plantations) is around 5 million ha (in the 2 provinces of Papua and West Papua), which indicates a great opportunity to be used as a sustainable source of food, animal feed and bioenergy.

Keywords: Bioenergy, feed, food, sago, sago waste, sustainable sources

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Food processing and food quality

Effect of coffee preparation on caffeine content

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Coffee is one of the most important agricultural crops in tropical regions. It is grown to make a beverage, popular all over the world, which has stimulating effects due to its caffeine content. Caffeine is the most widespread psychoactive stimulant in the world and coffee accounts for the highest amount of caffeine consumed worldwide. Besides its positive effects, several negative effects of caffeine on brain development in children, miscarriage and fecundability have been reported. Knowing the contents of their diets is essential especially for vulnerable groups (such as pregnant and lactating women, caffeine-sensitive people). Different methods of coffee preparation have evolved in different parts of the world and information from the scientific literature suggests that the method of preparation has an impact on the caffeine content of the beverage. Therefore, the aim of the research was to evaluate impact of beverage preparation method on caffeine content, while eliminating other variables influencing caffeine extraction. Twelve different brews of *Coffea arabica* from northern Tanzania were analysed using high-performance liquid chromatography with diode array detection at 264 nm. Beans of Bourbon variety, harvested during October – December of 2020, were washed and roasted at 220 to 240 °C for 15 minutes. All analysed samples were prepared using same grind setting and solid to liquid ratio of 6 g coffee to 100 ml of water. The beverages were prepared by immersion (various time and temperature), percolation, pressure methods and microwaved. The content of caffeine in the samples ranged from 35.2 $\pm$ 0.2 to 66.7 $\pm$ 8.6 mg of caffeine per 100 ml. Statistical analysis was performed using ANOVA single factor. The caffeine content in beverages prepared by immersion methods was significantly higher compared to percolation techniques. Microwaved samples showed no significant change in caffeine content. Obtained values were of compliance with intake recommendations of 200–300 mg day^{-1} set by European Food Safety Authority. Caffeine sensitive individuals should consider choosing percolation methods, as they show lower caffeine extraction. Whereas immersion and pressure methods may be more suitable for individuals seeking stimulating properties of caffeine.

Keywords: Brewing methods, caffeine, *Coffea arabica*, coffea spp., coffee, HPLC-DAD, human health

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Meeting local markets with sustainably processed foods – the dried mango flakes of Kitui county, Kenya

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The mango production sector in Kenya is affected by many inefficiencies and limited market opportunities. Lack of infrastructures, low access to global markets, inadequate market information and poor linkages coupled with the high seasonality and perishability of the fruit often lead to oversupply, heavy post-harvest losses, high price fluctuations and low profit margins for farm small holders. To tackle these challenges, the joint European-African STEP-UP research project has contributed to the upgrading of small-scale mango farm enterprises through the provision of technologies access and trainings on jointly defined market value addition strategies. Among the strategies identified, the processing through solar drying and commercialisation of locally produced mango flakes is expected to bring higher profit margins to local farmers while reducing production wastes. After two season of mango drying activities conducted between October 2019 and April 2021, a series of product consumer testing and sensory evaluations involving a total of 330 panellists was carried out in Germany and Kenya to determine the best market strategy for export and local market. The German survey has shown that the extrinsic attributes of the product are affecting the perception of intrinsic attributes for consumers with specific purchasing habit and values (enhancing their willingness to pay) indicating that German mango market can constitute a source of high profit margins for Kenyan farmers if the strategy is tailored to meet extrinsic attributes and sustainability preferences. Results from a second survey in Kenya on 6 varieties treated with 3 compounds revealed that honey treated mango flakes were preferred by the 31 semi-trained panellists, but this treatment was not affecting the sensorial scores of high value grafted mango varieties. Then, a third comparative survey to the German study was carried out in Kenya. Findings show that consumers display higher degrees of

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liking for provided mango flakes varieties, and their mango flakes consumption habits positively affect their evaluation of different sensorial attributes. Yet, individual values and perception of extrinsic attributes does not affect their low willingness to pay that is why local producers should focus on lower value varieties treated with honey for the local mango flakes market.

Keywords: Consumer preferences, intrinsic and extrinsic attributes, marketing strategies, online surveys, post harvest losses, processing, value addition, willingness to pay

Fermentation and germination effects on physiochemical and nutritive value of child feeds in northern Kenya

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Developing countries suffer from poor weaning diets, with inadequate calories, protein, and micro-nutrients, leading to high levels of malnutrition, morbidity, and mortality among children aged 6–24 months. Annually, malnutrition contributes to 45 % of under-five deaths, underscoring the urgency of accelerating the fight against malnutrition. In Kenya, significantly higher rates of malnutrition have been reported among pastorals' communities, especially in children aged 6–24 months. In Marsabit, child feeding practices focus on provision of multi-mix porridge as main sources of nutrients, however, malnutrition prevalence rates are high, maybe due to phytochemicals that exist naturally in plant foods, being bound and less bio-available. These phytochemicals can be altered by processing, like fermentation and germination. Microorganisms used in fermentation are capable of modifying bio-availability of phytochemicals in plant foods. This study aimed at investigating food processing methods, that could hinder bio-availability of nutrients and physiochemical composition of child feeds. The participatory approach study was conducted in Marsabit county, Northern Kenya, involving pastoral and agropastoral communities. Snowballing sampling technique was used to identify societal actors, who were mothers or caregivers of children aged 6–24 months. A total of 87 societal actors were identified and 9 FGDs conducted, based on ethnicity, women groups and region. FGD themes focused on the child feed ingredients, their accessibility, affordability and processing methods. A total of 9 porridge mix samples were collected and subjected for ongoing proximate analysis: 4 non-fermented, 4 fermented and 1 germinated. Preliminary findings indicate the societal partners have vast knowledge on optimal child feed-

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ing practices, can identify the different food types vital for child's growth and development, and foods that can be used when a child is unwell. Also, child feeds are available and accessible to mothers, but their nutritional value can be enhanced by selected affordable and acceptable food processing methods at the household and community level, such as fermentation. In conclusion, societal partners also incorporate food processing methods such as roasting, which reduce the content of nutrient inhibitors, increasing the bio-availability of nutrients and can be enhanced by other methods, including fermentation and germination for better outcomes.

Keywords: Bio-availability, child feeds, fermentation, food processing, germination, malnutrition

Solar food processing - ice production and drying - in an off-grid system in Kenya

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In coastal Kenya, lack of cold storage facilities and appropriate technologies result in huge losses for coastal fishermen as they transport fish to markets for sell and processing. Consequently, they are forced to sell their produce fresh, to dealers or at uneconomical prices. The warm weather in the region also hastens spoilage of fish leading to cases of post-harvest losses. It is also normally difficult to dry fish during the rainy season and at night. Sun drying on open grounds is prone to contamination and produce poor quality fish that cannot gain access to high value markets.

The public funded project SolCoolDry aims to support the fisherman by the development and set-up of a 100 % solar powered, off-grid system for the production of ice and drying of fish. The system is expected to produce 500 kg of ice and dry 500 kg of fish daily. The PV-electric operation of the flake ice machine in combination with adapted storage technology ensures optimal utilisation of the daily production capacity with an optimised plant operation. Furthermore, the solar thermal system is designed to provide a 24-hour operation of the solar tunnel dryer. Degradation processes of the material to be dried during the night hours can therewith be avoided. The system consists of a sea container with inverters as well as electric and thermal storages shaded by a roof of PV-modules and solar thermal collectors. Next to it, the solar tunnel dryer has been set up. A monitoring system allows the partners to keep an eye from remote at the operation behaviour and to support the local operators.

To guarantee a successful set up of the "whole containerized package" sent to the partners in Kenya, a video tutorial was created due to the restrictions caused by the Corona pandemic. Finally, the system was being assembled at the Mwazaro site (at the south coast of Kenya) by the local partners. The video tutorial as assembly instruction was extremely advantageous. The part-

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ners also kept weekly update online meetings to monitor the progress of delivery and installation of the SolCoolDry system.
Fish farmers will be trained on processing and quality assurance. Fraunhofer ISE and Innotech is partnering with Kenya Industrial Research and Development Institute (KIRDI), Kenya Marine and Fisheries Research Institute (KMFRI) and Technical University of Mombasa (TUM) to transfer the proposed technology package. With the help of these activities, a sustainable operation of the SolCoolDry-system will be supported.
In the presentation we will give a short overview of the project with focus on the commissioning and first results of the system operation in summer 2022.
The project is supported by funds of the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE).

Keywords: Ice production, drying, food processing, off grid, solar

Microbiological safety of farmed and wild harvested edible insects from East Africa

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Africa still lacks behind in terms of meeting its food security goals and food availability is often seasonal. Edible insects are part of the seasonal available diet in most communities within the savannah grasslands and forests. Locusts, grasshoppers, dung beetle larvae and termites are commonly harvested from the wild in Africa, while crickets and black soldier fly farming is widespread. Edible insects are highly perishable and traditional techniques like smoking, salting, frying, and sun drying used for preservation often leads to spoilage. Reports of increased diarrhea are well-documented during insect swarming, however, data on the contamination of insects with pathogenic and antibiotic resistant bacteria are rare. We therefore aimed to analyse the occurrence of these pathogens in 23 insect and six frass samples from different regions and production sites in Kenya, Uganda and Tanzania. *Salmonella*, diarrheic *Escherichia coli*, *Staphylococcus aureus* and *Bacillus cereus* (s.l.) were analysed. A questionnaire was used to collect information about the source of the insects; persons involved in the collection; processing techniques and process flow description. Initial results revealed a wide diversity, with the total aerobic bacterial count ranging from 10^2 to 6.3×10^9 CFU per gram of dried and powdered insect samples and from $<10^2$ up to 10^{10} CFU per gram frass. Coliform bacteria were detected in 9 of 23 insect and two of six frass samples, and *Bacillus cereus* (s.l.) species were detected in 20 of 23 insect samples with a maximum of 2×10^8 CFU g^{-1} in a cricket sample. Moreover, *staphylococci* were detected in 7 of 23 insect and five of six frass samples. The dung beetle samples contained the highest coliform load (n=3; $> 5 \times 10^4$ CFU g^{-1}). The ongoing detection and characterisation of pathogenic and antibiotic resistant bacteria will enlighten distribution and contamination of edible insects according to their source and harvesting style. This knowledge would help to increase the acceptance of edible insects.

Keywords: Antibiotic resistant, food safety, food security, pathogenic, preservation, protein

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Coffee bean drying shrinkage comparison by finite element simulations and real image processing

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One of the most important physical properties of the coffee grain to consider when drying is the surface area, seeing that the moisture diffusion is a function of the size of the grain. Also, the coffee bed represents a porous volume throughout which the drying air circulates, such porosity is also given by the seed's dimensions and void spaces within the grain layer. When the coffee bean is dried, a volumetric shrinkage occurs, and even though its change can be easily measured in terms of length, width and depth, the surface area variations must be approximated since the bean's shape is irregular. Contemplating this, three wet coffee grains (*Coffea arabica*) were 3D scanned and digitised, upon which a transient mass diffusion finite element method (FEM) simulation was performed from an initial moisture content of 55 % (w.b) until reaching the required moisture content of 10 % (w.b). The superficial area of the three grains was evaluated at different moisture content stages during the drying simulation process, so the ongoing shrinkage could be recorded. Afterwards, real coffee grains at 55 % (w.b) were laboratory-dried, keeping the same parameters as the simulation (air temperature, relative humidity, airflow, and direction); samples were removed at different moisture content levels and their parchment was withdrawn and spread on a cover glass; their image was taken and subsequently processed to obtain the actual surface area. Both the FEM simulation and the image processing results were compared, finding a level of similarity of 96.5 %, where an average 7.3 % volumetric shrinkage was observed. At the same time, the drying time was compared, displaying that both results shared an accurate and high similarity.

Keywords: *Coffea arabica*, coffee drying, image processing, mass diffusion, seed shrinkage

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Micronutrient profiles of pigeon peas and dark green leafy vegetables from Lindi region, Tanzania

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Pigeon peas (*Cajanus cajan* L.) are legumes with a high nutritional value acting as major source of protein of many tropical and subtropical regions of the world. Dark green leafy vegetables (DGLV) on the other hand are important sources of micronutrients and other phytochemicals. This study under the Vegi-Leg project evaluated amino acids (AAs) in pigeon peas (PPs) and minerals, carotenoids and phytates in PPs and DGLVs. PPs and various DGLVs were analysed for AA, minerals, carotenoids and phytate content using an amino acid analyser and ICP-OES and HPLC techniques.

The analyses of 'undehulled' local and improved genotypes of PPs revealed an excellent AA profile with 18 AAs and a (median) total of 19 gram/100 grams. Glutamatic acid and phenylalanine showed concentrations $\geq$ 2 gram /100 gram, and improved PPs showed higher lysine concentrations compared to local genotypes. The mineral analysis revealed high median concentrations of iron (2.4 mg/100g), zinc (2.1 mg/100g), calcium (80 mg/100g) and magnesium (123 mg/100g), but also a very high total phytate (IP5 plus IP6) concentration of 701 mg/100g.

DGLV such as Amaranth spp but also 'leaves' from conventional agriculture such as cassava and sweet potato represented very good sources of provitamin A ($>$ 4 mg beta-carotene/100 g fresh weight (FW), other carotenoids (lutein), iron (3.8 mg/100g FW), calcium (236 mg/100g FW) and magnesium (94 mg/100g FW). In general, the median phytate content of the leafy vegetables was very low (6.3 mg/100g FW), contrary to expectations and regarding previous publications. This study shows that PPs and DGLVs have the potential to improve dietary intake of specific macro and micronutrients and therefore promoting these foods can have a positive impact on food and nutrition security.

Keywords: Amino acids, carotenoids, dark green leafy vegetables, minerals, phytates, pigeon peas, Tanzania

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Evaluation of volatile compounds in a value-added jerky by incorporating Ajwain and Thyme essential oils

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There has been a growing interest and demand in the consumption of medicinal plants over the last two decades. Their extracts and essential oils became a fascinating trend in the food and pharmaceutical industries. They are considered a source of bioactive natural compounds with antioxidant, antifungal, antibacterial, and yet antiviral properties. For instance, Thyme (*Thymus vulgaris*), an aromatic plant and herb that belongs to the Lamiaceae family, with a grassy appearance that grows in many parts of the globe, has been used as a seasoning agent as well as a very valuable meat additive. Thyme essential oil (TEO) application in meat products appeals to food processors and consumers mainly due to its antimicrobial and flavoring properties. Moreover, we propose the application of Ajwain (*Trachyspermum ammi*) essential oil (AEO), a prominent fragrant herb belonging to the Apiaceae family, on meat products as a preservative and flavoring compound due to its similar properties to Thyme. Ajwain seeds, commonly used as a spice in Indian dishes, are small, oval-shaped, and pale brown, with a bitter and spicy taste and aroma like Thyme. Other various uses of Ajwain are food preservative, antioxidant, and natural medicine, particularly for digestive ailments. The current study evaluates the chemical composition of our jerky snack food, which has been subjected to different essential oil treatments. Hot air blanching (HAB) and oil treatment (OT) were applied to meat samples using two essential oil doses: 0.75 mL and 1.5 mL. All samples were dried after each treatment at 55°C for 6 hours. We considered that it was critical to analyse and quantify the chemical composition of the final product. A dual technique was proposed to identify and quantify volatile compounds using headspace solid-phase microextraction (HS-SPME) and gas chromatography-mass spectrometry (GC/MS). Our results showed that the chemical composition between TEO and AEO was indeed similar. However, applying those essential oil treatments had significant differences in the quantification of volatile compounds for the dried meat. Moreover, they are an excellent preservation alternative for our value-added jerky product.

Keywords: Ajwain essential oil, chemical composition, dried meat, jerky, thyme essential oil

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Assessment and quantification of new metabolites in quinoa (*Chenopodium quinoa* Willd.) using UHPLC-Q-Orbitrap mass spectrometer

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Quinoa (*Chenopodium quinoa* Willd.) is a pseudo-cereal originating from the mountain region of South America. Quinoa possesses excellent nutritional quality and contains numerous secondary metabolites acting as plant protection. Many of the metabolites also display biological activities and potential health benefits. The two principal groups of secondary metabolites in quinoa are phenolic acids and flavonoids. In this study, 56 various quinoa genotypes grown in the climatic conditions of the Czech Republic during the year 2021 were subjected to metabolomic analyses using a UHPLC-Q-Orbitrap high-resolution tandem mass spectrometer. Obtained data were processed in Xcalibur Quan Browser and Compound Discoverer software and compared to available scientific literature. As a result, eight flavonoids, two phenolic compounds, and one phenolic amid were detected and quantified in quinoa samples. The majority of them have never been quantified in quinoa before. The concentration of all 11 compounds was compared among red- and yellow-coloured seed samples of the same genotype. Red seeded genotypes had higher mean concentration rates of analysed metabolites than yellow seeded genotypes. Chemicals identified in absolutely all quinoa samples were isoquercetin, naringenin, pinocembrin, emodin, isorhamnetin from the flavonoid group, and salicylic acid as a phenolic compound. Isoquercetin was the metabolite with the highest concentration ranging from 0.138–9.907 μg g^{-1} in dry weight (DW). The lowest concentration was identified for naringenin, ranging from 0.002–0.179 μg DW g^{-1}. Three flavonoids were detected only in some genotypes – quercitrin (identified in 26 genotypes), taxifolin (identified in 25 genotypes), and vitexin (identified in 1 genotype), all of them having relatively low concentrations. Two chemicals, namely 4-hydroxybenzaldehyde (0.576–4.233 μg DW g^{-1}), a phenolic compound, and N-feruloyloctopamine (0.092–4.993 μg DW g^{-1}), a phenolic amid, have never been identified or quantified in quinoa before. Both are additionally the first compounds found in the genus Chenopodium and the family Chenopodiaceae. These findings showed that quinoa metabolomics is a potential area for further investigations since the variability of chemical compounds has not been fully explored yet.

Keywords: Flavonoids, liquid chromatography-mass spectrometry, metabolites

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Design, construction and testing of a solar-biomass flatbed dryer for maize cobs drying in Rwanda

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Maize is one of the most relevant cereal crops for human diet worldwide and specifically in sub-Saharan Africa due to its wide adaptability and nutritional value. The high-altitude regions in the tropics above 1500 m a.s.l. are characterised by low temperatures and abundant rainfall, making drying of maize cobs difficult. In this study, a solar-biomass hybrid flatbed dryer for drying maize cobs was designed, constructed and tested in the high-altitude maize producing volcanic regions of Rwanda. The dryer capacity is two tons of fresh maize cobs per drying batch. A low-cost biomass combustion unit was designed and constructed using locally available materials. The dryer was equipped with two fans, which are powered by a photovoltaic (PV) system. One fan was installed behind the heat exchanger to bring heated air into the plenum of the dryer. The other fan was installed at the air inlet of the combustion unit, in order to regulate the supply of combustion air. Airflow and temperature distribution in the combustion unit and the drying chamber were optimised by simulation with computational fluid dynamics (CFD) software. Size of solar arrays and batteries of the PV system was determined with MATLAB/Simulink model integrated with climate data for the target region. The technical performance will be on-site assessed, in terms of drying rate and dryer efficiency. Preliminary results show that the maize cobs bulk produced a static pressure of 120 Pa for a volumetric airflow of 1 $m^3\ s^{-1}$. Simulation of the PV system shows that the battery state of charge (SOC) remained above the threshold of 40 % for more than 25 days in a row during a typical harvesting period. The solar-biomass hybrid flatbed dryer can be used as a sustainable solution to smallholder farmers for handling maize cobs.

Keywords: Biomass energy, CFD, Matlab/Simulink, renewable energy, solar panels, ventilator test rig

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Unravelling the phenolic diversity of pigmented rice and their antidiabetic and anticancer properties

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Coloured rice, characterised by its red, purple, or black pericarp colours, has been grown and marketed for its dietary and therapeutical benefits. It constitutes phenolic acids, flavonoids, anthocyanins, and proanthocyanidins responsible for the anticancer properties of coloured rice. Furthermore, the resistant starch content of pigmented rice was attributed to its anti-diabetic properties. However, despite the broad claims about the importance of pigmented rice for human nutrition, the underlying metabolic diversity has not been systematically explored. This research profiled large diversity of coloured rice samples (n=300) for the glycemic index, phenolic content, antioxidant capacity, and inhibitory effects against colon cancer. Black rice has shown significant differences in the anthocyanin and proanthocyanidin contents compared with red rice. However, it did not show a significant difference in the antioxidant assays such as DPPH, ABTS, and FRAP. Generally, pigmented rice has shown greater free phenolic content than its bound counterpart. In terms of starch content and composition, there is a wide variation observed across the pigmented rice panel. Mathematical models such as artificial neural networks and random forest modelling classified the rice lines according to their nutritional content and properties. Furthermore, it has been shown that bound phenolics have a greater contribution to rice's colour. GWAS analysis was used to identify the genes responsible for the anticancer and anti-diabetic properties. In addition, elite cultivars in terms of phenolic content and nutritional properties were determined. Correlation networks demonstrated the phenolic profile of the pigmented rice's dietary benefits. This research has shown the influence of flavonoids on rice's anti-diabetic and anticancer properties. We contest that this research will be utilised for breeding rice that can alleviate non-communicable diseases such as cancer and diabetes.

Keywords: Anticancer, antidiabetic, coloured rice, phenolics, rice, starch

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Improvement of the drying performance of pre-cooked beans (*Phaseolus vulgaris*) through ultrasonic-assisted hulling

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Beans are among the most versatile and widely consumed staple foods worldwide. They are highly nutritious and contain high levels of dietary fibers, complex carbohydrates, proteins, essential vitamins, and minerals that are indispensable to human wellbeing. Due to their given importance, the development of processing methods for hard-to-cook beans for the preparation of instant end-products is of great interest, especially in developing countries. Thus, this study focused on investigating the influence of ultrasonic-assisted dehulling on the drying behaviour of pre-cooked beans as a viable alternative to the present drying approaches. Red kidney beans (*Phaseolus vulgaris*), unhulled (UHB) and dehulled via ultrasonication (HB/UT), were used for the experimental analysis. The cooking time of beans was determined based on sensory evaluation, with 50 and 25 min proving to be optimal for UHB and HB/UT, respectively. Afterwards, the pre-cooked samples were dried in a high-precision through-flow laboratory dryer (HPD-TF3+) at 30, 50, and 70 °C with an air velocity of 0.20 ms^{-1} and specific humidity of 10 g kg^{-1}. Results revealed a faster moisture transfer of the HB/UT beans compared to UHB beans at $p < 0.05$, which was attributed to the lower resistance to moisture diffusion induced by the hull removal. Henceforth, a reduction of drying time up to 73.3 % was ascertained experimentally. A generalised semi-empirical model was developed from the analysis of the drying data, which was capable of predicting the drying behaviour of beans with $R^2 \geq 0.990$ and MAPE ≤ 10.0 %. In terms of colour, UHB and HB/UT beans differed significantly at $p < 0.05$ for redness a*, yellowness b*, hue angle H*, and chroma c* across all drying conditions, while no significant differences were observed for luminosity L*. Microstructural analysis revealed comparable structures after drying at 30 and 50 °C, with beans exhibiting an intact cellular structure. Temperatures of 70 °C, on the other hand, degraded the cellular integrity of beans by breaking down the cell wall boundaries, especially in HB/UT beans. In conclusion, ultrasonic-assisted hulling has demonstrated a great potential for improving the drying performance of beans, thereby making it a viable alternative for practical applications.

Keywords: Beans, cooking, dehulling, drying, microstructure, ultrasonic-assisted

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Extra virgin olive oil stability study by OXITEST® reactor

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Extra virgin olive oil is an excellent source of natural fat, originated in the Mediterranean basin. Nowadays, olive oil is expanded and appreciated worldwide. Besides its positive content, olive oil carries substances that are not stable, and its durability depends on the storage conditions such as packaging, temperature, light, and oxygen. In this research two packaging materials (glass and Tetra Pak®) were used. To simulate household conditions, the headspace was created by removing half of the content. Each sample was stored under two different storage conditions (dark & cold, light & warm). Oxidation stability was identified by an OXITEST® reactor which is an innovative instrument to measure the oxidative stability of fat foods based on the monitoring of pressure over a period of time in analytical chambers, where the sample is submitted at high oxygen pressure and high temperature. The induction period, which is the time required to reach the starting point of oxidation, was the shortest for olive oils with headspace under light & warm conditions indicating their susceptibility to rancidity. No difference was found between packaging materials and their stability. Both dark glass bottle and Tetra Pak® container appear to be suitable packaging materials. To conclude, to maintain the quality of extra virgin olive oils as long as possible, it is necessary to limit the headspace in the container and reduce exposure to light conditions. It is desired to consider how much olive oil one household could consume and accordingly buy a smaller package to prevent the formation of an ample headspace and thus prevent faster oxidation.

Keywords: Evoo, *Olea europaea*, oxidation, stability

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Eco-design of biodegradable food packaging from corn husk for the preservation of local foods in Benin

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The ever-increasing development of industrial activities has led to a proliferation of various types of packaging used in the food and drink sector. Over the last ten decades, there has been a proliferation of plastic packaging worldwide, mainly in the food and beverage industries, which absorb about 65 % of it, compared to about 35 % for other sectors. However, due to its non-biodegradable nature, plastic packaging poses an environmental pollution problem. The environmental and health hazards caused by plastic packaging are increasing and have been proven by scientific studies. Moreover, the government of Benin has adopted law N°2017–39 of 26 December 2017 on the prohibition of the use of non-biodegradable plastic bags. In an international context where sustainable development is a major priority, the development of biodegradable materials is a major challenge that offers an alternative to synthetic polymers produced by petrochemicals. To this end, the objective of the study was to design biodegradable food packaging from corn husk. A field survey was conducted to investigate the availability of corn husk. The functional analysis method was used to produce prototype packaging. Parameters such as opacity, heat resistance, water absorption, and tensile strength at break were the main characteristics evaluated. Thus, the physical, mechanical and economic parameters of the eco-designed packaging show that it is opaque, especially to ultraviolet radiation (OP = 262.10 $\pm$ 1.71); has a heat resistance $\geq$ 150 °C with a breaking stress of 4.45 $\pm$ 0.35 Mpa. Pale yellow in colour, it has a water absorption capacity of 200 g m^2. The developed packaging is economically profitable since the Net Present Value = 6,672,160 FCFA is positive for 5.3 tonnes of maize spathe valorized and the Internal Rate of Return's 31.13 %. The profitability index's 1.71. This results in a gain of 0.71 FCFA after 1 FCFA invested. The study provides a sustainable and ecological solution to the problems of businesses by providing them with biodegradable food packaging from agricultural residues, which is simple to use and adapted to the local context, at an affordable price and environmentally friendly, contributing to sustainable development goals(SDG) 8, 12, 13 and 15.

Keywords: Biodegradable packaging, corn husk, eco-design, environment, foods, sustainable development

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Mathematical modelling of oven drying kinetics of pretreated cassava flour

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Cassava (*Manihot esculenta* Crantz) is a widely available agricultural commodity and a significant source of calories in Indonesia. Cassava flour, which is processed via pretreatment and drying, is one of the derivative products of cassava. The application of heat during drying helps to achieve the good quality of the final product. The popular method for drying cassava in the tropical regions is sun drying. The disadvantage of this drying method is spending much time due to ambient temperature during dying. Some of the challenges in processing cassava flour include the presence of high-temperature heating and the reaction between sugar and protein, which can result in the Maillard reaction, which is a major concern for cassava processing in general. The purpose of this study was to determine the model of oven drying characteristics of pretreated cassava flour empirically and fundamentally. In this study, the following experimental variations were DIP (soaked in distilled water for 3 days at room temperature 24°C); DIB (soaked in distilled water for 2 days then blanched at 100°C for 3 minutes); and BDI (blanched at 100°C for 3 minutes then soaked in distilled water for 2 days). The results showed that the Midilli model satisfactorily described the drying behaviour of pretreated cassava flour with high coefficient of determination values ($R^2 = 0.9808$) and low values of sum square error (SSE = 0.02734). The Midili model could suitably express oven drying characteristics of pretreated cassava flour than the other models since it has shown best accuracy to the experimental data as compared to the other models (Newton, Two-term, Logarithmic, and Page).

Keywords: Blanching, cassava flour, modelling, oven drying, soaking

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Heavy metals in Zambian fish as potential hazard for food safety and nutrition security

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In Zambia fish is the main animal food source of the poor population, especially for women and children and has been shown to be a great source of micronutrients (iron, calcium, zinc) that are usually lacking in the Zambian diet. However, only limited information on the heavy metal contents of consumed fish species is available, despite heavy metal pollution being one of Zambia's biggest environmental problems. As heavy metals are highly toxic even in small doses, eating heavy metal contaminated food has serious health outcomes in consumers. Therefore, this study aimed to elucidate the heavy metal contents of approximately 40 fish species in various kinds of processing to ensure both food and consumer safety.

Fish were collected from Zambian water bodies, where high levels of heavy metal contamination are documented, such as Kafue River, Lake Itezhi tezhi and Lake Kariba. Samples were prepared following local customs (big and medium fish fileted, small fish left whole) and analysed for cadmium and lead via ICP-MS (inductively coupled plasma mass spectrometry) as well as for mercury via AAS (atomic absorption spectrometry). Results were compared with legal maximum levels formulated either by FAO/WHO (lead, mercury) or EFSA (cadmium).

All analysed fresh samples were below the legal maximum levels for either heavy metal. Processed big and medium fish showed higher lead contents than their fresh counterparts, even than compared on a dry weight basis, but were still below the legal maximum level of 0.3 mg kg^{-1}. However, a sample of Mbubu (*Mormyrus lacerde*) and a sample of Nsuku (*Serranochromis robustus*) contained about 1.5 or 1.7 times as much mercury as the legal maximum level of 0.5 mg kg^{-1}. Regarding small, processed fish, two samples of dried Kapenta (*Limnothrissa miodon*) contained about double the amount of the legal cadmium levels of 0.1 mg kg^{-1}. One of these samples also contained about 1.5 times as much lead as the legal maximum level.

Thus, apart from these few samples with excessive heavy metal contents, fish from Zambia, were found to be generally safe for human consumption and should be strongly considered in strategies against micronutrient malnutrition.

Keywords: Fish, food safety, heavy metal contamination, nutrition security

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Effect of clarification on physical-chemical properties and nutrient retention of pressed and blended cashew apple juice

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The cashew apple is a nutritious pseudo fruit of the cashew tree, after the nut. It is highly perishable and has an astringency taste, which both hinder its utilisation. This study was designed to optimise the clarification of cashew apple juice (CAJ) using gelatine, and assess the effect of clarification on physical-chemical properties and nutrient retention of pressed and blended CAJ. Pressed and blended CAJ was treated with gelatine concentrations (0, 0.025, 0.05, 0.1, 0.2, 0.3 and 0.4 g L^{-1}) at room temperature for 1, 2, 4, 6, 8, 10 and 12 h. Both clarified and un-clarified juice were analysed for tannin, total phenol, β-carotene, vitamin C, sugar, minerals, physical-chemical qualities (titratable acidity, total soluble solids, pH), and antioxidant activity. The results showed that tannin was optimally reduced from 217.6 mg/100 ml TAE to 24.6 mg/100 ml TAE for pressed CAJ, and from 258.0 mg/100 ml TAE to 55.0 mg/100 ml TAE for blended CAJ, using 0.2 g of gelatine in a liter of juice, for two hours at room temperature (24–26°C). Blended and pressed CAJ with and without clarification showed no significant difference in pH, total soluble solids, and titratable acidity, $p < 0.05$. However, blended CAJ had higher contents of total phenol, β-carotene, vitamin C, sugar, potassium, calcium, zinc, iron, phosphorus, and antioxidant activities $p < 0.05$, while pressed CAJ had a higher magnesium content at $p < 0.05$. The use of a low concentration of gelatine in a liter of either blended or pressed CAJ yielded high quality and less astringent CAJ. Though both juices exhibited high nutrient contents, blended CAJ presents more nutritional benefits than the pressed. The technology performed well at room temperature and therefore can be disseminated for use in households, small-medium scale juice processors in low resource settings.

Keywords: Cashew apple juice, clarification, gelatine, pressing and blending, tannin

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Physical properties of foam powder produced from white-fleshed and yellow-fleshed cassava (*Manihot esculenta*) varieties

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Cassava is susceptible to accelerated physiological deterioration after harvest, and when stored in the fresh state, it may result in huge economic losses and food insecurity among 500 million people who depend on it for food and livelihood in Africa, South America and Southeast Asia. Processing cassava by foam mat drying (FMD) has shown important advantages in previous studies such as improved carotenoids retention, reduction of cyanogenic glucosides to safe levels, improved functional properties and improved colour. The cassava foam powder (CFP) produced by FMD can be regarded as a stable, functional cassava product that may be reconstituted in food preparations.

Until now, no study about physical properties of CFP came to our knowledge. Therefore, this study evaluated the physical properties of CFP produced from white and yellow cassava varieties, and compared them with cassava pulp powder (CPP) i.e. non-foamed powder. Cassava foams prepared under optimal conditions were dried and milled to foam powder. The white CFP and yellow CFP had true density of 1.466 g cm^{-3} and 1.534 g cm^{-3}, respectively, and porosity of 59.0 % and 62.8 %, respectively. The flow properties determined include Carr's index (CI), Hausner ratio (HR), angle of repose (θ) and coefficient of static friction (μs). The CFPs had better flow properties compared to the CPPs. Electron micrographs of the CFPs revealed that the foam powders were irregular, coalesced, and larger in particle size than CPPs, which were regular, discrete and smaller in particle size. All the powders had normal probability distribution in particle sizes. The rehydration kinetics simulated by the Azuara model showed an estimated equilibrium water gain (WGeq) of 0.760-1.429]g g^{-1} at temperatures between 30 °C and 70 °C. The CFPs had a higher rehydration capacity than CPPs. Rehydration capacity of the powders increased with temperature. Adsorption isotherm of the powders was best fit by the Halsey model, and revealed type III sorption isotherm profiles. The Guggenheim-Anderson-De Boer (GAB) monolayer moisture content of the powders ranged between 0.036-0.092 g g^{-1} db. FMD may have improved flow properties and rehydration of cassava.

Keywords: Adsorption isotherm, foam mat drying, foam powder, rehydration

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Oil extraction from mango kernels using a mechanical screw press

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Mango (*Mangifera indica* L.) is one of the most important tropical fruits with an annual production of over 55 million tons. Mango kernels, as one of the main by-products of mango processing, have the potential to be used as a fat resource for human consumption, animal feed and cosmetics. The mango kernels have an oil content of up to 16 %. In this study, mechanical oil extraction of mango kernels using a commercial screw press was evaluated. The mango fruits cv. Kent imported from Brazil were purchased at a local market in Stuttgart. Prior to the oil extraction, the mango kernels were separated from the fruits, cut into small pieces and dried at 40 °C until a moisture content of 9 % was achieved. The experiment was conducted at a screw rotational speed of 20 rpm and a nozzle diameter of 5 mm. Oil recovery, oil extraction efficiency and throughput were determined. In addition, the oil quality parameters, such as water content, acid number, iodine and peroxide values, were measured. It was determined that oil recovery was 52.7 %, oil extraction efficiency was 30.0 % and throughput was 1.7 kg h^{-1}. After sedimentation of the crude oil, around 68.9 % sedimented oil was obtained. The sedimented oil had a water content of 0.04 $\pm$ 0.00 %, an acid value of 3.64 $\pm$ 0.11 mg KOH g^{-1}, an iodine value of 57.26 $\pm$ 0.07 g I2 100 g^{-1} and a peroxide value of 0.26 $\pm$ 0.00 mEq O_2 kg^{-1}. The results showed that by applying a proper pre-treatment, the mango kernel oil can be feasibly extracted from mango kernels using a mechanical screw press. To optimise the oil extraction, different pretreatment methods, screw rotational speeds and nozzle diameters of a screw press and moisture content of press material must be investigated in future studies.

Keywords: Expeller, mango seeds, plant oil, press-cake, protein

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Influence of drying temperature on drying behaviour and quality of mango kernels

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One of the main by-products of mango production are the kernels. To utilise the mango kernels, drying is an important step for later applications. In this study, the effect of different drying temperatures on drying behaviour and some quality parameters of mango kernels was investigated. Mango fruits cv. Kent originally from Brazil were used in this study. The drying experiment was conducted at temperatures of 40, 50 and 60 °C using a high precision laboratory dryer. Air velocity and absolute humidity of the air were held constant at 0.2 m s^{-1} and 10 g kg^{-1}, respectively. Mass loss from the mango kernels was recorded at constant intervals of 5 min. Furthermore, the quality of dried mango kernels was determined in terms of colour, total phenolic content, flavonoids and total tannin content. The results showed that the moisture content decreased gradually until the desired moisture content of 9 % was accomplished. With an increase in the temperature, the total drying time decreased remarkably. Colour of the mango kernels was substantially influenced during the drying process. Although, there were no significant differences in colour parameters (L*a*b*) among mango kernels dried at different temperatures at $p < 0.05$. The mango kernels dried at 60 °C showed the highest total phenolic content (83.4 ± 2.9 GAE mg g^{-1} of the dried sample), flavonoids (63.3 ± 1.5 mg g^{-1} of the dried sample), and tannin content (77.3 ± 1.5 mg g^{-1} of the dried sample) compared to those dried at the other temperatures ($p < 0.05$). It was observed that the choice of the drying temperature could change the ingredients of the mango kernels. In addition, a drying temperature of 60 °C was found to be the optimal operating temperature for mango kernels regarding their quality and drying time.

Keywords: Drying, mango kernels, processing temperature, utilisation

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Microbial contamination during slaughter and retail points of the pork value chain in Uganda

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Bacterial foodborne pathogens remain a global public health concern with a huge health burden comparable to diseases like malaria, HIV / AIDs, and tuberculosis. Animal source foods which include beef, pork, and dairy products have been implicated in the transmission of foodborne pathogens. Pigs and pork have specifically been implicated in the transmission of non-typhoidal *Salmonella* (NTS) through the pork value chain to humans. Uganda ranks top in consumption of pork in East Africa yet the safety of pork and the risks of NTS infection to meat handlers in this chain remain uninvestigated. This study, therefore, aims to establish levels of contamination at the point of slaughter and retail of the pork value chain and the factors that influence those levels. It will also establish the genetic relatedness of NTS from pigs, humans, and the slaughter and retail environments. A cross-sectional study design will be employed. Pigs presented for slaughter will be sampled, and the carcasses tracked to the point of retail and sampled too. Samples from the slaughter and retail environments which include surfaces, tools, and water used for dressing will be collected. Laboratory microbial analyses will be carried out to determine the presence and levels of bacteria i.e. NTS and total coliforms. Meat handlers along this chain will also be sampled and investigated for the presence of NTS. Data to be collected include demographic data and risk factors for infection with NTS in humans using structured questionnaires. An observational checklist will be used to collect information on factors at slaughter and retail points that influence the occurrence of contamination. In-depth interviews will also be conducted with key informants to collect more information on hygiene practices. The findings will highlight levels of contamination at different points, providing useful data for control and mitigation of cross-contamination in the pork value chain in Uganda thus improving pork safety and occupational health. It will also highlight whether pigs in Uganda are a reservoir for zoonotic NTS.

Keywords: Microbial contamination, non-typhoidal *Salmonella*, pork value chain, Uganda.

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Instrumental texture profile analyses of pounded yam produced from yam genotypes of contrasting pounding quality

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Traditional roots and tubers breeding techniques often target yield, disease/pest resistance and nutrition as important traits for breeding programs, while consumer food quality preferences such as textural quality are often neglected. Textural quality is important to consumers of pounded yam, a popularly consumed doughy food product made from yam in Nigeria. The RTBfoods Project is targeted at developing medium-to-high throughput methods for roots and tubers, to evaluate preferred food quality attributes such as textural quality, and applying them as important traits in breeding pipelines. This study developed a standard operating protocol (SOP) for evaluating instrumental texture profile (ITPA) of pounded yam. Pounded yam was prepared from four varieties of *D. rotundata* with contrasting textural quality (TDr1401220, TDrMeccakusa, TDr1401593 and TDr1400158) based on a SOP (RTBfoods_-E.6.6_SOP). ITPA was conducted on the pounded yam by means of texturometer (TVT 6700, Perten) at product temperature of 45°C under standard parameter conditions.

Statistic t-test reveal good repeatability of the textural attributes (hardness, adhesiveness, cohesiveness, springiness, stickiness, gumminess & chewiness), while analysis of variance (ANOVA) evidenced the significant contrast ($p < 0.0001$) in textural attributes between the varieties. The first two principal components (PCA) of the textural data explained 94.2 % of variation and the varieties were grouped into unique clusters within the components space. The textural quality attributes that contribute the most to variation among the varieties are cohesiveness, springiness, chewiness and gumminess, which are attributes particularly associated with the varieties TDr 1400158 and TDr Meccakusa within the components' space. This outcome seem agreeable with the perception by pounded yam consumers that good quality pounded yam must be stretchable, mouldable, and moderately firm. Discriminant analysis also supported the PCA results. Pearson correlation coefficients between the attributes were generally significant ($p < 0.0001$), such as between cohesive-

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ness and springiness ($r = 0.96$).
It is expected that descriptive sensory textural scores and overall consumer acceptance scores may afterwards be correlated with these highly discriminant instrumental attributes and useful regression models developed for medium-throughput instrumental estimation of sensory textural attributes as perceived by the consumers.

Keywords: Discriminant analysis, PCA, pearson correlation, pounded yam, textural attributes, texture profile analysis, yams

Combined spermine and spermidine postharvest treatment attenuates pomegranate cv 'sawa' fruit physiological losses and maintain fruit quality by improving biochemical and antioxidative attributes at ambient conditions

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Fresh fruit are perishable commodity prone to rapid postharvest losses in quantity and quality. Certain postharvest intervention including postharvest treatment, treatment with polyamines, had been known to reduce these losses. Keeping in view a study was carried out to explore the effect of exogenous application of polyamines on fruit quality of pome-granate cv. 'Sawa'. In this experiment, physiological mature pomegranate fruit were dipped in 2 mM aqueous solution of polyamines [Spermine (SPM), Spermidine (SPD)] individually as well as in combination using Tween-20 as a surfactant for 5 minutes and were kept at ambient conditions (25 $\pm$ 2°C, 60–65 % RH) for 15 days. Experimental design was two factors factorial under CRD (Completely Randomised Design) arrangement. The treated fruit were observed for fruit physiological attributes (ethylene production, respira-tion rate, fruit weight loss), aril biochemical attributes [total soluble solids (TSS), titratable acidity (TA), ripening index (TSS:TA ratio)] and aril antioxidative attributes [total phenol-ic contents (TPC), total antioxidative activity, anthocyanin, activities of superoxide dis-mutase (SOD), peroxidase (POD) and catalase (CAT) enzymes]. Results indicated that all the treated and untreated fruit exhibited physiological, biochemical and antioxidative fruit quality losses at ambient conditions as the shelf period progressed. However, at day-15 of shelf, pomegranate fruit treated with combined SPM + SPD treatment exhibited lower ethylene production (0.18 μmole kg^{-1}hr-), respiration rate(0.54 mmole $kg^{-1}hr^{-1}$), fruit weight loss(10 %), fruit firmness (24 N), CAT enzyme activity and higher TA (0.69 %), TPC (107 mg GAE $100g^{-1}$), antioxidative activity (56 % DPPH) and activities of SOD (31 U mg^{-1} of protein) and CAT (7.4 U mg^{-1} of protein) enzymes as compared to untreated or other treatment. Overall, combined SPM and SPD treatment lessened overall fruit losses and maintained fruit quality of pomegranate fruit at ambient conditions irrespective to shelf duration.

Keywords: Fruit quality, polyamines, postharvest water dipping, *Punica granatum*

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Antibacterial resistant *Escherichia coli* isolated from slaughter sites in Yenagoa metropolis Bayelsa state

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Substantial use of antimicrobials across the world occurs in livestock production of meat, milk and eggs for human consumption thereby making antibiotic resistance (AMR) of global concern to both human and animal health. The spread of AMR generated at farm level can be due to human exposure to AMR pathogens either by direct contact, contamination of livestock products or wide spread release into the environmental. A large number of ruminant animals slaughtered daily at slaughter sites for human consumption come from different sources with limited record of their health status or any treatment received prior to slaughtering. This may contribute as a driver to AMR spread owing to the fact that slaughter waste disposal may not be appropriate at such sites. Two major slaughter sites were sampled in Yenagoa metropolis of Bayelsa state to determine antibiotic resistant bacteria. Site 1 was labelled as SW while site 2 was labelled as TA. Four waste samples were collected as solid mass from each site and stored in pre-labelled sterile sample bottles. This was taken to the laboratory for bacteria isolation after enrichment for antibiogram analysis using the following antibiotics penicillin (10μg Disk load), augmentin (30μg), cloxacillin (5μg), erythromycin (15μg), gentamicin (10μg), ofloxacin (5μg), streptomycin (10μg), tetracycline (30μg), and ampicillin (10μg). *Pseudomonas aeruginosa* and *Escherichia coli* were isolated using bacteria specific agar and characterised individually prior to antibiogram analysis. Of the 4 samples collected from site SW, *E. coli* was isolated from 2 samples, while only 1 sample from site TA showed the presence of *E. coli*. Antibiogram results for *E. coli* were interesting as the bacteria isolated from site SW and TA was resistant to all the antibiotics tested except ofloxacin. Antibiogram results for the other antibiotics was 0.00 mm at their respective concentration (μg disk load). Antibiogram results obtained with ofloxacin was 28mm, 31mm (SW) and 32mm (TA); respectively.
It can be concluded that *E. coli* isolated from both slaughter sites exhibit antibiotic resistance against 8 of the antibiotics tested except 1 (ofloxacin).

Keywords: Antibiotics, antimicrobial resistance, *Escherichia coli*, livestock products, slaughter sites

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Food consumption and sustainable food production

Understanding consumers' perceptions of meat safety and quality at pre-harvest and harvest stages of production in Afghanistan – a qualitative content analysis

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Food safety issues in meat may originate at different stages of production. However, there is little understanding of how consumers in developing countries perceive meat safety and quality at each stage. This study aimed at studying consumers' perception of meat quality and safety in Afghanistan with a distinct focus on evaluating perceptions at the production, slaughtering & processing stages along the supply chain. To this end, qualitative data were collected through seven focus group discussions in Kabul and Bamyan, Afghanistan between September - December 2020. A total of 52 respondents, mostly young and educated, were recruited. The Total Food Quality Model (TFQM) was used as a conceptual framework for evaluating consumers' meat quality judgment before and after purchase, and the data were analysed based on qualitative content analysis using MAXQDA version 2020. Our findings revealed that before purchase, freshness, place-of-origin, safety, and Halal slaughtering, while after purchase, taste and tenderness are the most important quality attributes. At the production stage, the meat of both the sedentary and nomadic ruminants is perceived higher in quality and animal welfare, with lower food safety hazards due to feeding on natural pasture. While the meat of urban-raised ruminants is perceived as unsafe and of lower quality and animal welfare due to feeding on food-waste. At the slaughtering and processing stage, supermarket meat is perceived better in hygiene, but not fresh. In contrast, butchery meat is perceived as fresh, and natural, but unhygienic. According to the respondents, food fraud is practised at all stages of meat production. In addition, FG participants in this study relied heavily on and trusted traditional butchery despite associating the higher prevalence of food safety hazards, and lower level of animal welfare in the system compared to modern supermarkets and slaughterhouses. Hence, this behaviour may suggest a phenomenon called "optimistic bias" among consumers. Albeit adding interesting insights, the findings in this study cannot be generalised due to the nature of qualitative data collection. Hence, further studies based on quantitative data are required with a larger and more diverse sample size to validate the results of our study.

Keywords: Nomadic, pasture-type, place-of-origin, traditional butchery

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Responses of the local food system during the first wave of COVID-19 from Honduras

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The lockdowns in consequence of the COVID-19 pandemic impacted livelihoods and food security of households around the globe but most severely vulnerable households in developing countries. While evidence is available about how COVID-19 generally affected low-income countries, the specific dynamics of local food system responses and effects on food security in rural areas has not been addressed. This research seeks to understand a) how the local food system changed under COVID-19-related mobility restrictions, b) how coffee farmers' households coped with food insecurity and, c) what the role of coffee cooperatives could be in supporting households to cope with food insecurity and to increase their resilience.

The study approaches food security through four components, which are food security as an outcome, food system activities with actors and factors, resilience capacities, and shocks and stressors. It is based on a mixed-methods approach, combining a structured household survey with semi-structured qualitative interviews with households, representatives of cooperatives as well as other food system actors.

We found that during mobility restrictions, 50 % of coffee producing households were forced to reduce the quality and quantity of food consumed compared to the previous year. Although food suppliers changed their strategies to procure fresh food, and hence played a key role in maintaining the availability of fresh food at the beginning of the COVID-19 crisis, more than half of households were not confident how to ensure their food security given rising food prices and local shortages. Coffee cooperatives supported their members by providing food assistance and cash transfers as well as credits. A better integration between the needs of member households and the goals of cooperatives, e.g. through adjusting cooperative statutes to include other crops than vegetables or including a mandate to be also a consumer cooperative, could play a key role in boosting local food security.

Keywords: Food security, food system, households, resilience capacity

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How can cascara authorisation in the European Union contribute to sustainable development of the global coffee value chain? A multiple case study

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During coffee cultivation, production and consumption a wide variety of by-products is generated. One of the present applications for one of the most substantial coffee waste fractions lies in the food sector: a non-alcoholic beverage called cascara, which is based on an upcycled dried coffee cherry. However, companies operating within the European Union had to stop commercialising cascara beverages, as in the spring of 2017 the ingredient was classified as 'novel' and prohibited from marketing in the EU. The term 'Novel Food' refers to food or food ingredients coming from plants, animals, microorganisms, cell cultures, minerals, and production technologies, which were not used for human consumption on the European market before 15 May 1997. However, such novel ingredients may enhance the sustainability of global food value chains.
The study followed three research objectives. First, was an assessment of the competitive environment of cascara beverage producers in the EU. Next, understanding cascara prohibition effects on businesses, interactions between stakeholders in the ongoing authorisation process, and overall cascara trade perspectives in the EU. Third, identifying potential impacts on the sustainability of the global coffee value chain caused by a forthcoming authorisation of cascara for beverages production in the EU in the year 2022.
The analysis of the competitive environment defined a high bargaining power of buyers and a high level of substitutes, which were making the European soft drinks industry less attractive for cascara producers. It was determined that for the market success of Novel Food like cascara, informational marketing is needed to help customers overcome food neophobia. The research results showed that the inclusion of cascara utilisation in the coffee value chain would not address the coffee price volatility problem. However, the most underpaid actors – farmers could generate additional profits. Environmental impacts would take place slowly even if the beverage gained a foothold in the EU. Social impacts were the least expected in terms of the coffee VC sustainability. The effects, however, will depend on various factors such as the scale of cascara utilisation in the EU (also beyond the beverage industry) and the corporate social responsibility of big corporations.

Keywords: Agri-food waste, by-products, coffee, European Union, food value chain, Novel Food, soft drinks, sustainability, valorisation

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Evaluation of the attractiveness of different packaging designs for child food products by Beninese customers

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Child malnutrition is a major problem in Benin, where 31 % of children under five years suffer from stunting and 5 % from wasting. Artisanal production of affordable, tasty and nutritious child food by local women entrepreneurs could help mitigate the problem. However, minimising spoilage and keeping technophile customers on board requires appropriate, attractive packaging.
To investigate the influence of packaging design elements (attributes) and their characteristics (attribute levels) on the evaluation of packaging attractiveness by Beninese child food customers, we conducted a conjoint experiment. The experiment was embedded in an online survey, which was completed by 110 child food customers in the wider area around Parakou, North Benin, in January 2022. The attributes [colour design, background element, pictorial elements (mother; giraffe), nutritional information] and attribute levels included were derived from previous own investigations. 15 packaging designs were created (D-efficient design) and randomly displayed to participants who were asked to rate the attractiveness of each packaging design on a scale from 1 to 10.
The rating of packaging designs ranged from a mean of 5.68 (SD 2.15) for the lowest rated to 7.49 (SD 1.68) for the highest rated design. The design's influence on the evaluation of attractiveness was significant, as shown by the regression model (R^2 = 11.8 %, $p < 0.001$). The most important design element was the background element, followed by the pictorial representation of a woman and colour. Less important were the pictorial representation of a giraffe and nutritional information. Of the background attribute levels, the blackboard had the highest part-worth utility with a coefficient of 0.78. The illustration of a traditional woman generated a part worth utility of 0.47 followed by a contemporary illustration of a woman (0.39) and the base category with no illustration (0.00). Of the colour design attribute levels, a traditional reddish pattern generated the highest part-worth utility (0.46).
Our results indicate that packaging designs displaying traditional symbols might attract Beninese child food customers. However, our model only explains about 12 % of the data's variance. Further research is needed to determine other impatcs like sociodemographics' and food shopping environments'.

Keywords: Child food packaging, malnutrition Benin, parental food choices influenced by packaging

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Consumers' preferences and willingness to pay for nutrient-dense, shelf-stable pigeon pea-based noodles for sustainable consumption

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The study aimed to assess consumer willingness to pay, perceived value, and drivers for their buying decision. A total of 107 consumers residing in different locations in Ruangwa and Nachingwea districts in the Lindi region, Tanzania were involved. Structured questionnaire was used to collect the information. The profile of the developed product and specification of each attribute was described to consumers before evaluating the attributes and rating their choice on a 5-point scale as well as proposing the price will pay. Data were analysed using SPSS, mean and standard deviations were used to summarise age and the proposed price. Frequencies were used to summarise preference ratings, buying interest, and driver for their choice. A Chi-square test was used to determine the relationship between consumer characteristics and samples. Logit regression analysis was used to determine predictors for willingness to pay for the developed pigeon pea-based product (PPBN). Average age was 38.79 $\pm$ 11.9 (SD) years, expenditure was 13,625 $\pm$ 1653.8 (SD) Tshs/week and 25,176 $\pm$ 5485.8 (SD) Tshs/week during harvesting and lean season respectively. About 78 % of consumers were married, 64 % had primary education, 69 % were farmers, and 53 % prefer sample PPBN193. There was no significant difference in choosing the sample among the age group, sex, marital status, education, source of income, and amount of money spent per week at $p < 0.05$. Colour, taste, and aroma of noodle for both samples was perceived to be good with differences in mouthfeel among samples. About 86 % of consumers are willing to buy developed PPBN at a price of 1633.64 $\pm$ 593.32(SD)Tshs for 500g. The Hosmer and Lemeshow $\chi 2$ test of 8.082, with p-value =0. 426 indicated that the data fit well in the model. The Nagelkerke R^2 explained 35 % variability in willingness to pay for the developed products. Expenditure per day, package size, and price significantly contributed to the model. Availability of preferred and acceptable nutrient-dense shelf-stable food products, at an affordable price, will make the food available to all people at all times for sustainable consumption. This will contribute to the reduction of global challenges on food and nutrition security.

Keywords: Consumers' preferences, perceived value, pigeon pea-based noodles, willingness to pay

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Consumer preference and willingness to pay for egg attributes from hen fed insect-based feed

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In the recent years the growth of population has led to the increased demand of protein rich meals. This has led to the need to increase protein rich meals such as eggs and in order to do so there is a need to do so in an environmentally friendly and cost-effective manner. Insect-based poultry feed has shown the prospects of increasing production in a cost-effective manner. However, research on consumers preference and willingness to pay for eggs from hens fed on insect-based feed is limited. This study utilised choice based conjoint analysis (CBCA) to determine consumer preferences and willingness to pay (WTP) for four attributes of eggs. Multistage sampling procedure was used to collect data from 200 consumers in Kiambu County. The results of CBCA revealed significant heterogeneity in preference among egg consumers. Our results revealed that 65.5 % were aware of the use of insects as feed. Consumers' have shown preference for insect-based feed in production of eggs with 70.5 % willing to consume these eggs. The results show that consumers least preferred large eggs and were willing to pay the lowest at Ksh. 2 and most preferred golden yellow yolk eggs and were willing to pay Ksh. 18. It was also found that price was the most important attribute in determining consumer preferences with 86 percent of consumers showing concern. The results indicate that consumers were more willing to pay 10 percent more for golden yolk eggs at Ksh 11 than the average price of conventional eggs. Producers should consider the differences in preferences among consumers to increase the uptake of eggs produced from commercial BSFL-based feed. This work contributes to the limited knowledge on insect-based feeds and paves way for further linkages between farmers, public private partners, policy makers and consumers.

Keywords: Choice based conjoint analysis, consumer preference, egg attributes, insect-based feed

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Sustainable meat labeling in Latin America and the Caribbean: Initiatives, developments, and bottlenecks

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Scientific research is increasingly showing that food production is responsible for the environment, which is in contrast to greater consumer awareness. In this regard, sustainability seals for meat have emerged, which offer guarantees that production is based on principles of e.g., animal welfare, zero-deforestation, or carbon neutrality. Since research on this subject is scarce, we aim to identify and analyse developments of this type of labeling in Latin America and the Caribbean through a qualitative-descriptive study based on primary and secondary sources. The results show that although the conditions in the region are favourable for the development of sustainable meat labeling, progress to date has not been significant. The development is uneven, the labels identified correspond mainly to large producers and exporters in the region, with particularly noticeable lags in Central America and the Caribbean. Even countries with a strong livestock tradition, such as Brazil, Uruguay, Argentina, and Mexico, show differences between them. While Brazil and Uruguay promote labeling, the others rely on traditional production, since quality criteria currently in place are still sufficient to maintain market shares. In Colombia, however, producers seem to have understood that sustainability is gradually acquiring greater value providing opportunities to position their products nationally and abroad. Another regional characteristic is the absence of a coordinating element: initiatives have begun spontaneously and gradually in different contexts and lack institutions or mechanisms that facilitate feedback. Among the positive aspects, Uruguay and Brazil demonstrate collaboration among public and private institutions, in addition to the involvement of independent certifying bodies. This is fundamental when it comes to guarantees for the consumers and good governance. However, in these countries, as well as Colombia and Argentina, exclusive private labeling strategies continue, which can be affect reliability. There is a diversity of seals in the market, which and makes it difficult for consumers to differentiate between those that do or do not have rigorous certification processes. Despite these challenges, the transition towards sustainability is inevitable. This process will, however, not happen spontaneously but must be coordinated with other strategies and the actions of the numerous actors involved in the sector.

Keywords: Animal welfare, carbon neutrality, sustainable intensification, sustainable labeling, sustainable livestock farming

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COVID-19 and beef consumption in Colombia: Effects on consumer preferences and beliefs

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The COVID-19 pandemic has brought impacts on the food system in several ways, such as on the supply and demand of food or changes in consumer preferences. The effects on consumer preferences are directly resulting from changes in people's daily lives and living conditions. Households challenge income reductions and, in turn, change their food consumption decisions, causing e.g., substitution effects or panic buying behaviour. However, little is known yet about the magnitude of these effects but needs to be analysed to define actions and policies for crisis mitigation and achieving food system resilience and food security. In this study, we estimate the effect of the COVID-19 lockdown on changes in food consumer preferences in Colombia, applying a logit model approach for seven attributes, namely animal welfare, environmental sustainability, information on the origin and manufacturing of food, food appearance, food price, fair payment to the producer, and food packaging. In addition, we provide an analysis of changes in beef consumption during the lockdown since the beef industry is among Colombia's most important agricultural activities and is heavily affected by substitution effects. Data was obtained in July 2020 during the peak of the COVID-19 lockdown in Colombia, through a virtual survey with 581 food consumers in the four major cities Bogotá, Medellín, Cali, and Barranquilla. Our results show that consumer beliefs regarding these attributes remained mostly stable, but that income is a determining factor for the decision to consume certain types of food, such as beef, rather than for possible changes in beliefs. This means that income ends up being decisive for the consumption of food such as beef and that, for its part, it does not have a greater weight in the change of beliefs of the people surveyed. The results will help the food system actors in defining interventions for achieving food security and resilience.

Keywords: Consumer preferences, COVID-19, food chain, food system, logit model, sustainability

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Market and business strategy analysis of Panamanian specialty coffee

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The coffee industry underwent major changes during the crisis of the 1990s and faced many challenges. In Panama, the crisis resulted in the abandonment of coffee production by many producers. However, some of them persevered, resulting in a local specialty coffee boom several years later. The Lamastus family is partly responsible for this boom. Thanks to their knowledge, their great experience, but above all thanks to their passion for coffee, they founded the Specialty Coffee Association of Panama in collaboration with other regional producers. Today, Panamanian coffee has managed to forge a reputation as one of the best coffees in the world.
Lamastus Family Estates recently began to increase their production by acquiring two new fincas, to build on the success of Panamanian specialty coffee, thus doubling their production. To avoid a situation where supply exceeds demand, this study evaluates the international market for Panamanian specialty coffee and performs a business analysis. Practical recommendations are given, to focus on the main levers at their disposal to increase sales.
For this purpose, this study has been based on various reports, scientific documents, and literature about specialty coffee markets in different countries. Expert interviews were conducted to obtain more accurate data for some countries. An index revealing the most promising markets for specialty coffee was created. The business analysis was mainly done by identifying the main competitors of the finca, analysing their communication tools and through a SWOT analysis and a Risk Management Matrix.
The market for specialty coffee is not saturated and continues to grow. Several promising markets have been identified and the Lamastus family has the capacity to develop or consolidate. Different trends and consumption preferences have been identified in different markets. The finca's communication tools are well mastered, but with potential for improvement. The positioning of their coffee as a luxury product is partly achieved but needs to be consolidated and further developed. There are no risks that currently endanger the operation's activities, but many risks have been identified. However, the strengths and opportunities of the operation should allow for the mitigation or elimination of these risks.

Keywords: Business analysis, geisha, market analysis, panama, specialty coffee

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Understanding the contribution and dynamics of wild harvest in Turkana county

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Compared to domesticated plant food sources, wild edible plants tend to be overlooked. However, there is substantial evidence that wild edible plants have great potential for improving variety and diversity of diets as well as micronutrient intakes of local communities while lowering the cost of nutritious diets for households. This mixed-method study elucidated the diversity and consumption of available wild edible plants and the local perceptions of the communities living in Loima and Turkana South sub-counties in Kenya. In 2020, data was collected using 12 gender-disaggregated focus group discussions and a cross-sectional survey including 360 randomly selected households. In total 73 wild edible plants were listed of which 24 were consumed in the six-month reference period by 48.5 % of the surveyed households. Consumption frequency and contribution made by the wild edible plants to the household food consumption varied for each plant and household. All the surveyed households (96 %) were classified as severely food insecure. The mean household food insecurity access score did not differ significantly between households that reported consumption of wild edible plants (14.4 ± 5.4) and those who did not (13.8 ± 6.2), $p > 0.05$. However, significantly bigger proportions of households that consumed wild edible plants than those that did not reported consuming foods they had wished not to consume (92.4 % versus 88.4 %, $p < 0.05$) as well as having to eat fewer meals than normal (96.5 % versus 90.7 %, $p < 0.05$) to cope with food insecurity. Overall, 57.1 % of the participants harbored positive attitude towards wild edible plants. While the general attitude did not differ significantly between wild edible plants among consumers and non-consumers, the study demonstrates that positive attitudes about wild edible plants is associated with wild food consumption. Long distance to harvest sites, lack of knowledge about them, their seasonality and how to prepare them coupled by unfavourable attitudes and perceptions are the probable reasons for not consuming wild edible plants. Wild edible plants potentially bridge food and dietary deficits in food insecure households although their consumption is still limited and they may not be among households' favourites foods.

Keywords: Dietary quality, food security, turkana, wild edible plants

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Understanding the motivation of community health volunteers (CHVs) in promoting nutritious child-feeding practices in Benin drylands

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Benin Republic is one of the West African countries with severe micronutrient deficiencies among children. To address this issue, nutrition education has been promoted by government and development actors, engaging local communities in promoting good nutrition, health and long-term well-being. The nutrition education system relies on Community Health Volunteers (CHVs) operating through community-based volunteer networks such as Nutrition Assistance Groups (GANs) and Food and Nutritional Surveillance Committees (CSANs) supporting and relaying nutrition experts to local targets. Our transdisciplinary research studied the motivations and actions of CHVs in the current community-based child nutrition and health education system, in order to contribute to inform sustainable and scalable child-nutrition interventions. To achieve this, participant observation was carried out during nutrition education activities conducted by two local NGOs in seven villages in the districts of Nikki and Banikoara in Northern Benin. The activities involving the CHVs focused on active health biometric screening, child-growth monitoring, cooking demonstration and communication for social behaviour change. Two expert consultation workshops were organised with 23 nutrition education experts, including 17 women, to understand what NGO field workers and supervisors think about the CHVs in the local nutrition education system. Five extended group discussions were organised engaging 99 community relays and volunteers (including 76 women) in exchanges about current nutrition education process. Preliminary results from the study revealed that CHVs have more extrinsic motivation (allowances, training perdiems, divine blessings, social prestige, social networking, social influence, etc.) than intrinsic motivation (family welfare, learning and new skills). Cases of amotivation were not noted with the CHVs, but rather among the targets, who sometimes find no interest in nutrition education activities. Local communities conceptualise this as ignorance (nyinru sariru), which is seen as the root cause of failure in efforts to improve child-feeding practices. The observed low level of self-determination among CHVs added to the gender power relations influences the effectiveness of the nutrition education system in place. These findings are useful for further research and for improving nutrition education policies, with a view to building an appropriate and respectful community-dialogue model in African drylands.

Keywords: Child-feeding, community health volunteer, motivation, nutrition education, self-determination

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Perceptions on criteria influencing complementary food choices among (agro)pastoralist mothers in northern Kenya

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Mothers' child-feeding practices vary depending on environmental, social, economic and cultural conditions that influence their personal food environments and hence criteria for food choice. In Kenya, child feeding practices vary within populations even in similar geographical areas. This study aims at understanding reasons for these differences by investigating mothers' perceptions on criteria belonging to their personal food environment and how they evaluate main food items according to these criteria. The study was conducted in Marsabit county, northern Kenya. Mothers are classified according to location (urban, peri-urban, rural) and ethnicity (Borana, Rendille, Sakuye, Burji) with their respective livelihood focus. Qualitative methods were used where 13 focus group discussions were conducted with 4 women groups; 1 rural Rendille (pastoral), 1 rural Burji (agricultural), 1 peri-urban Sakuye (agro-pastoral), and 1 urban Borana (agro-pastoral). Common food items used for child feeding were listed followed by rating of foods (from 5 to 0) against these criteria; healthiness, child acceptance, availability/accessibility, affordability and convenience.

Marked differences were found between the foods used by rural livestock-keeping Rendille and the other three groups focusing on crop-farming and/or on purchased food. Availability, accessibility and affordability were all linked to local food production and seasons. To make food items affordable, mothers bought them in small quantities and on credit. Healthiness was related to hygiene, foods that boosted immunity, nutrient-rich and promoted child growth. Time used to prepare food, fuel and water needed in cooking the foods determined convenience. Preparation processes such as fermentation and dehulling made foods less convenient whereas ready-to-eat foods and mixed dishes were convenient. Children liked soft, tasty and sweet foods but also having a variety increased desirability. Cultural foods unique to specific ethnic groups were liked by their children but not by those of other ethnic groups.

This study shows mothers' perceptions on their food environment. It reveals the similarities and differences in perceptions and practices among mothers from one region but different specific locations and ethnicities. These insights are important to inform efforts to improve child feeding practices as they need to consider mothers' food environments with their opportunities and limitations to create appropriate interventions.

Keywords: (Agro)pastoralists, child foods, food choices, food environment, mothers, northern Kenya, perceptions, rating

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Endogenous knowledges and practices in child feeding among caregivers in northern Benin

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Inadequate results of governmental and non-governmental child nutrition programmes are also related to limited knowledge of mothers' knowledge and practices. In the context of developing countries with poor socio-economic situation and low empowerment of women, appropriate endogenous knowledge and practices would be very important for improving child nutrition. They are appropriate because they are adapted to the local context and can be easily adopted by mothers. The aim of this study was to describe endogenous child feeding knowledge and practices among caregivers in North Benin.

Checklist-based individual interviews (24) were conducted with caregivers from the Fulani, Baatombu and Gando ethnic groups in Banikoara and Nikki communities. These interviews focused on endogenous knowledge and practices related to child feeding. In addition, focus groups (4) were organised with caregivers to discuss in more detail issues that emerged from the individual interviews. The recordings of the interviews were transcribed and then content analysed using MAXQDA software.

Five main themes on endogenous knowledge and practices of child feeding were found: Breastfeeding, complementary feeding, weaning, child care and hygiene. In the first month of breastfeeding, the caregivers use herbal teas to fight illnesses of the child and help him/her grow well. In addition, there are various methods to increase the mother's milk production using foods and herbal products to help the baby get more breast milk. In complementary feeding, they use fortified foods that are enriched with other foods or plants. To make weaning easier for the children and to avoid negative effects, the caregivers use different methods, such as mixing certain foods with breast milk or applying herbal ointments to the breast. Five diseases recurred among the children, namely stomach ache, diarrhoea, malaria, cough and fever. Herbal tea treatment was used for each illness.

The caregivers have interesting knowledge and practices that could be relevant, affordable and accessible for improving child nutrition and rearing at the local level. It seems important to analyse their effectiveness in order to integrate them into nutrition education materials and make them useful for other mothers in the fight against child malnutrition.

Keywords: Caregivers, child feeding, endogenous knowledges and practices, herbal tea

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Barriers and enablers to healthy and sustainable food systems in Ethiopia

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Healthy and sustainable food systems are indispensable for combating the triple burden of malnutrition. Without improving the food systems, the efforts to control multiple forms of malnutrition would be undermined. The purpose of this study is to identify the barriers and enablers for healthy and sustainable food systems in Ethiopia. A qualitative study was used to explore the barriers and enablers of various sub-components of the food systems. The study was designed in such a way that the perspectives of rural and urban dwellers and agrarian and pastoral livelihoods of Ethiopia are represented. The study captured the views federal and regional level informants as well. Data were gathered through focus group discussions (FGDs) and key informant interview (KIIs). More than 60 KIIs with decision makers, researchers and academicians were conducted. Twelve FGDs were organised with urban consumers, farmers, youth and women's group.

The major enable to the national food systems is the presence of comprehensive policy environment. Nutrition is also enjoying increasing attention by various stakeholders. Currently multisectoral nutrition interventions including nutrition sensitive agriculture and social protection programmes are being implemented at scale. The government has adopted promising strategic directions, including cluster farming and lowland wheat initiative for boosting production. The integrated agro-industrial parks initiative helps to modernize the value chain and reduce food loss. Presence of the health extension program platform offers a special opportunity for promoting nutrition literacy and implementing nutrition programmes at grassroots level. However, the food systems are constrained by multiple barriers including: lack of political stability, uncontrolled population growth, subsistence rain-fed agriculture, lack of support to large-scale farming, weak agricultural cooperatives, uncontrolled food price, uncontrolled export of healthy foods, food safety irregularities, low nutrition literacy, and demotivation of frontline health and agriculture workers.

Efforts to transform the agriculture system must be accelerated. Supporting large-scale farming and scaling up initiatives of cluster and market-led farming, and lowland wheat production should be maintained. However, the initiatives need to mainstream production diversification as well. Building agricultural cooperatives' capacity, directly linking them with consumer cooperatives, and strengthening consumer protection agency, are vital.

Keywords: Food systems

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Eliciting willingness to pay for quality maize and beans: Evidence from experimental auctions in Tanzania

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Using the incentive-compatible Becker-DeGroot-Marschak mechanism, we estimate the willingness-to-pay (WTP) for different quality maize and beans grades in Tanzania using data from a household survey and experimental auctions involving 555 participants. Specifically, we estimate consumers' observable and unobservable quality premiums on the different types of maize and beans. We consider three types of maize and beans quality grades;(1) unsorted and unlabeled; (2) sorted and unlabeled grade; and (3) sorted and labeled. Results indicate that respondents were willing to pay a premium for the sorted and labeled quality grades of maize and beans but asked for a huge discount for the unsorted grade. We also found that the premium associated with the observable quality was much higher than the value of the unobservable quality. In percentage terms, consumers were willing to pay more by 25 % and 14 % for the sorted over the unsorted grades of maize and beans. However, consumers were only WTP to pay more for the unobservable quality by 4 % and 2 % for the labeled grades of maize and beans. These results are pretty robust to different model specifications. The results also indicate that the main factors influencing the WTP for the maize products are asset ownership and geographical location. Respondents from households with more assets expressed a higher WTP for maize products than those with fewer assets. Similarly, the age and education of the respondent and the incidence of food-related sickness influenced the WTP for the different quality bean grades. Furthermore, results from the unconditional quantile regression model show the impact of the individual covariates on the WTP for maize and beans are not the same across the WTP distribution. Generally, respondents in the upper quantile of the WTP distribution expressed a higher WTP for the sorted and labeled grades than those in the lower quantiles. In the same vein, the effects of the other factors, e.g., assets, education, and land ownership, were much larger in the upper quantiles of the distribution than in the lower quantiles.

Keywords: Beans, experimental auctions, maize, Tanzania, willingness to pay

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Influence of institutional arrangements on the choice of vertical coordination strategic options in the sorghum supply chain in Kisumu county, Kenya

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Vertical coordination in agriculture has received popularity in recent years. They have emerged to transform farm enterprises from subsistence farming to commercial-oriented sorghum production for industrial use. Drivers motivating farm enterprise owners to engage in the different vertical coordination strategic options were not clear in the literature. Institutional arrangements were hypothesised to play a role alongside the socio-economic and institutional factors. The study bridged this gap by characterising the institutional arrangements and determining the effects of institutional arrangements on the choice of vertical coordination strategic options. A stratified sampling technique was used to randomly select 266 sorghum farm enterprise owners in Nyando Sub-county, Kisumu County. Descriptive statistics and Multivariate probit model were used in data analysis. Descriptive statistics revealed that the majority of the sorghum producers targeted coordinated options especially contractors and processors. The results justified that the choice of spot market was influenced by a young age, more sorghum experience, less farm sizes, fair price expectation, less payment delay, more bargaining power, transportation disarrangement, distance to the collection point and grade uncertainty. The choice of contractors was influenced by less farm sizes, quality inspection, payment delay, more bargaining power, transportation arrangement, distance to the collection point and less technical support. For sorghum producers choosing processors, off-farm income, more land size, lesser payment delays, less bargaining power and transportation disarrangement influenced their choice positively. The study recommended the use of standardised quality grading systems, price premiums for producers due to delayed payments and reasonable ways of sharing risks between the actors in order for them to access and utilise the new, lucrative and emerging cereal markets.

Keywords: Institutional arrangements, supply chain, vertical coordination, vertical coordination strategic options

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Food value chains of rural areas in sub-Saharan Africa

Tailor-made microcredit for smallholder dairy farmers; improving the dairy sector

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The dairy sector has been recognised as a potential profitable enterprise for smallholder dairy farmers in Zambia and Malawi. It provides a valuable source of regular income and contributes to food and nutrition security. However, this enterprise is currently characterised by low productivity due to poor access to agriculture financial services, resulting in inadequate animal feed resources, poor pasture development, unavailability of water, poor reproductive performance of dairy cows, untimely disease control and others. Furthermore, smallholder farmers are generally the most financially excluded group within the agriculture sector. Agricultural financing remains one of the critical enablers to facilitate growth within the sector. Micro Financing Institutions are seen as an opportunity for increased agricultural productivity and enhanced economic development. Therefore this project aims at creating a tailor-made microcredit package for smallholder dairy farmers calling for different stakeholders in the dairy sector. The project will use a participatory approach where a needs assessment will be done in the already existing diary groups or cooperatives.

Keywords: Microcredit, smallholder dairy farmers, stakeholders, tailor-made

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Organic farming for sustainable agriculture in sub-saharan Africa

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Over 65 % of approximately 750 million people in sub-Saharan Africa (SSA) work in the agricultural sector, which is responsible for more than a quarter of gross domestic product (GDP) in the majority of these countries. Agricultural products account for about 20 % of Africa's international trade. However, the depletion of African soil is a significant cause of low agricultural yields, which pushes farmers to use excessive chemical fertilisers. The adverse effects of continuous use of chemical fertilisers without integrated soil fertility management (ISFM) include soil degradation, acidity, and nutrient loss, which result in low soil biomass. Moreover, the prices of chemical fertilisers are skyrocketing beyond the reach of SSA smallholder farmers. Faced with the problems mentioned above, which are aggravated by the effects of climate change, SSA smallholder farmers will not only need an improvement in agricultural output but also the production of quality and organic produce, ultimately leading to environmental, social, and economic sustainability. The backdrop of this review necessitates the whole idea of organic farming for sustainable agriculture in sub-Saharan Africa. The objective of this proposal is to promote organic farming through the use of organic fertiliser in sub-Saharan Africa. The proposed programme entails the following three projects:
Project I: Training of farmers on good agricultural practices and linking them to suppliers of organic agro-inputs and the market for organic products in Kenya
Project II: Training of farmers on the manufacture of earthworm compost in Ethiopia
Project III: Production and marketing of organic fertilisers through animal droppings, plant debris, and organic waste in Nigeria and Togo

Keywords: Fertiliser, organic farming, sustainability

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Renewable energy in Africa

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Agriculture accounts for 30 to 40 % of total Gross domestic product in Africa, and a majority Energy is essential to our society to ensure our quality of life and to underpin all other elements of our economy. Renewable energy technologies offer the promise of clean, abundant energy gathered from self-renewing resources such as the sun, wind, earth, and plants. Africa is one of the rich continents in which you found all this resources.
The sunny continental can produce enough energy for the world in 300 × 300 km only the reason of high number for sunny hour (1800 h in Africa to 1000 h in Europe). Hydropower, the main current RE resource in West Africa, is strongly sensitive to monsoon rainfall variability, which has led to power crises in the past. Therefore, solar and wind power could play a stronger role in the future as countries move to power systems with high shares of RE. Without forget the geothermal water which the temperature can reach up to 78°C in 2000 m deep.
For example, at the end of 2020 in north Africa Tunisia had about 400MW of installed renewable energy capacity of which 244 MW was wind power, 89 MW solar power (79 MW by private entities and 10 MW by STEG), and 62 MW of hydroelectric power. However, in west Africa part of Nigeria is blessed with abundant Renewable Energy resources that have not been fully exploited; these renewable resources have the potentials to change the status quo of power generation and consumption in the country.

Keywords: Africa, agriculture, geothermal, hydropower, renewable energy, solar power

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Analysis of rice value chain in West Africa: Case of Mali, Nigeria and Togo

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Rice is one of the most consumed cereals in West Africa. It is used in the preparation of several dishes. Unfortunately, local production cannot meet local demand. In Nigeria, around 71 % of needs are covered by the local production, around 55 % in Mali and around 45 % in Togo. This situation seems paradoxical in view of the assets available to these countries and in view of the potential represented by the rice value chain for their economic development. Convinced that these countries can achieve food self-sufficiency in rice if adequate actions are taken, we have undertaken this study on Änalysis of rice value chain in West Africa: case of Mali, Nigeria and Togoto make our contribution to this objective.

The SWOT analysis of the rice value chain (VC) in these three countries allowed us to identify several weaknesses. We note among others, low business linkages between VC actors, low mechanisation, poor water control, difficulty of access for small producers to financial services, low yields, malfunctioning supply chains, high post-harvest losses, underdeveloped research, no trained farmers, environmental pollution etc. From this analysis we have proposed a number of solutions such as improve business linkages between VC actors, increase investment in machinery acquisition, irrigation system building and Research & Development, improve access of small producers to financial services, improve processing technology and adequate utilisation of rice by products, train producers, develop services along the VC etc. These solutions can be implemented by the actors of the VC, support organisations and policy makers.

Keywords: Rice, solutions, SWOT analysis, value chain

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Nutrition security and cosmetic industry nexus along the snail value chain in sub-Sahara Africa

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Global population increase and climate change pose enormous pressure on the existing food systems. On the other hand, an increase in per capita income has led to lifestyle changes towards a preference for high value organic and natural cosmetic products. The aforementioned scenario call for the adoption of novel and climate-smart innovations in the development of food and cosmetic systems. Heliciculture or snail farming is an emerging and promising farming that presents a greater potential for agroecological farming and bioeconomic business model. The snail value chain presents a lucrative agribusiness that can significantly contribute to poverty alleviation and nutrition security in sub-Saharan Africa. Snail meat contain approximately 60 % protein with by-products that include slime and calcium carbonate. The slime that is harvested from snails is an important ingredient in the production of cosmetics. Furthermore, the snail shells contain calcium carbonate that is can be used in the manufacture of animal feeds and liming of fishponds. Despite the economic, environmental, and social benefits of heliciculture, the lack of awareness and research has delayed the adoption of snail production and utilisation. Therefore, the main thrust of this review is to present in summary the potential of the snail value chain for economic development in sub-Sahara Africa. The review will focus on analysing the potential benefits, systems of production, associated risks, and future outlook when fully adopted.

Keywords: Cosmetics, heliciculture, nutrition, sub-Sahara Africa

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Prevalence and risk factors promoting the onset of Newcastle disease in local poultry farming in north of Togo

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Newcastle disease is a highly contagious viral disease of poultry with significant economic consequences especially in developing countries. This study was conducted to determine the prevalence and identify factors promoting the occurrence and persistence of Newcastle disease in the Kara and Savannah regions of Togo. To achieve this goal, a survey was conducted from February to March 2020 in 378 households and 1552 blood samples were taken from non-vaccinated traditional chickens. The hemagglutination inhibition test was performed on the serological samples to determine seroprevalence. In general, the prevalence of Newcastle disease in the Kara region ($37.96 \pm 3.45\,\%$) is significantly higher than the prevalence in the Savannah region ($29.50 \pm 3.25\,\%$). In the Kara region, the prefectures of Binah ($56.48 \pm 9.35\,\%$), Bassar ($54.63 \pm 9.38\,\%$), Kéran ($41.67 \pm 9.29\,\%$), and Kozah ($47.22 \pm 9.41\,\%$) have the highest prevalences ; and the values obtained in the prefectures of Binah, Bassar, and Kozah are approximately statistically equal. The prefectures of Oti ($48.15 \pm 9.42\,\%$) and Tandjoaré ($41.67 \pm 9.29\,\%$) are the prefectures with the highest prevalence in the Savannah region. Also the occurrence of the disease is higher in the dry season than in the rainy season. The proximity of local chickens to reservoirs of the virus, especially wild birds, the structure of henhouses, the bad management of morbid and dead animals, the movement of animals and people involved in the marketing of local chickens, breeding practices, the insufficient measure of sanitary prophylaxis and the low rate of immunisation coverage are the main factors favouring the emergence, dissemination, persistence of the disease in the traditional breeding systems in northern Togo and negatively impacts the income of rural farmers.

Keywords: Local poultry farming, Newcastle disease, prevalence, risks factors

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Effect of community-based buck selection and utilisation on production performance of progeny under smallholder farmers' management

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The aim of this study was to evaluate the effect of buck selection through community-based breeding programme (CBBP) on the performance of goat progenies. The study was conducted in Mzimba and Nsanje districts of Malawi. A total of 955 progenies (458 from Zombwe Extension Planning Area and 497 from Magoti EPA) from selected bucks were used to evaluate genetic improvements of selective breeding. A total of 105 farmers (65 farmers from Zombwe and 40 farmers from Magoti EPA) were interviewed to assess the adoption and impact of the breeding programme and utilisation of the selected bucks. General linear model procedures were employed to evaluate selective breeding progress based on body weight of progenies of base flocks and selected bucks. Results revealed that birth weight of progenies of selected bucks (2.53 ± 0.460 kg) were significantly ($p < 0.001$) heavier than base flock progenies (2.38 ± 0.453 kg). There was also a significant improvement in body weight in subsequent growth stages, at pre-weaning and weaning ($p < 0.001$). Means for pre-weaning weight for the progenies was (8.49 ± 1.836 kg) while for the base flock progenies was (6.93 ± 1.718 kg). Mean for weaning weights were as follows: (13.40 ± 1.891 kg) and (11.72 ± 2.494 kg) for progenies of selected bucks and progenies of the base flock respectively, from both EPAs. Significant variation across districts were observed. Differences in body weight of progenies across study districts were observed, whereby kids born from Magoti EPA had significantly higher weights than kids born in Zombwe EPA ($p < 0.001$). This could be as a result of a combination of genetic, environmental and management variations. Positive correlation coefficients between body weight and scrotal circumference across all growth stages and in both EPAs were recorded.
On the importance of CBBP, most farmers responded that the breeding programme is important as they have benefited in terms of improvement in body weight of the kids, sold their goats at higher prices from the extra cash from the sale of high value stocks, as well as the domestic consumption of goat meat. Results further showed that 57.5 % and 41.5 % of farmers from Magoti and Zombwe EPAs responded that CBBP is important.

Keywords: Livestock management, Malawi, small-scale farmers

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Promoting the production and marketing of orange fleshed sweet potato through capacity building of rural farmers in western Kenya

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Orange-fleshed sweet potato (OFSP) is a sweet potato cultivar that is a leading case of a vitamin A product that is promoted and embraced by the target cooperative society in Western Kenya. It has better agronomic and nutritional traits, including faster maturity, high yield potential, and endowed with rich nutrients. About 60 % of the households in the Western region live below the poverty line. Thus, production and marketing of OFSP has the potential to contribute to food security, increased incomes, and reduction of nutritional deficit that are poverty related. However, OFSP production and marketing are yet to be fully utilised in the region. Production is limited since it is currently being done by a cooperative society but not with the entire community despite the premium benefits associated with it. There is an established market of Organi Limited that process the sweet potato into bread and buns for sale in the local supermarkets. Additionally, there is an upcoming factory being constructed at the nearby county offering further markets for OFSP. There is therefore need to sensitize the community to adopt the production of this variety to provide raw materials for the two factories. This project intends to address the following objectives: provision of capacity building to the local farmers in identified locations to improve OFSP production; and to link the producing farmers to the readily available markets. These will be achieved by community mobilisation, sensitisation, and capacity building on the benefits associated with orange fleshed sweet potato production and commercialisation, this will help in advancing marketing of OFSP leading to achieving the universal goals. This will provide employment opportunity to the local farmers, improve nutrition and income hence reducing poverty.

Keywords: Capacity building, marketing, orange fleshed sweet potato, production

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Establishment of a consumer eggs production and marketing unit in the region of segou in Mali

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Livestock is a very important activity occupying a prominent place in the Malian economy. It is the main source of livelihood for more than 30 % of the Malian population and contributes 13.6 % to the gross domestic product (GDP). It also contributes nearly 80 % to the incomes of rural populations and about 20 % to export earnings. (INSTAT, 2017).

In Mali, poultry farming is currently developing. National programs, set up by the agriculture administrations, chambers of agriculture or even Non-Governmental Organisation and International institutions (FAO) are working to boost this sector throughout the country

The consumer eggs production is a rapidly expanding value chain in the Ségou region as local production is facing pressure as the demand is high and locals are forced to import the egg from Bamako. This is a risk in layer business as the distance is too much and poses risks on the quality of the eggs and presses an upper limit of the minimum price of the product. Normally a locally produced egg costs 75 francs CFA and the one from Bamako costs 100 francs CFA this justifies why we should have it locally produced.

The overall objective of this project is to set up a production and marketing unit for quality eggs as an animal protein for improved nutritional wellbeing of people in Segou region.

The choice of breed for production is the Delkab white which is characterised by high egg production with moderate food consumption, early maturation at productive age, and unpretentious character environmental conditions.

Keywords: Delkab white, eggs, poultry, production

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Improving child nutrition through avoidance of aflatoxin in rural areas of Africa (a case study of northern Nigeria)

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In sub-Saharan Africa, a shocking twenty-eight million children are experiencing stunted growth due to malnutrition. This prevents them from developing to their full potential mentally, physically and it is largely irreversible. It is estimated that malnutrition contributes to more than one third of all child deaths. It affects the child's development due to lack of food and nutrition needed for growth and thriving. Nutrition is a foundation for steady brain architecture.

Nigeria has the second highest burden of stunted children in the world, with a national prevalence rate of 32 percent of children under five. An estimated 2 million children in Nigeria suffer from severe acute malnutrition (SAM), but only two out of every 10 children affected is currently reached with treatment. Aflatoxin is a mycotoxin responsible for contamination of agricultural products and Africa is highly susceptible to aflatoxin contamination. The kernel of groundnut and maize are easily contaminated by aflatoxin. The major cause of contamination is poor handling at every point of contact. The body systems of children are known for easy absorption of substances from food which poses a threat to their health because these chemicals are highly carcinogenic and the lowest levels of exposure can result in measurable human health impacts.

This project aims to sensitize rural inhabitants on the handling of maize and groundnut which constitute the bulk of children food formulation. Improving the average northern children nutrition by optimum use of available resources and building awareness all through the localities.

Keywords: Aflatoxin, groundnut, maize, malnutrition

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Promotion of organic vegetable agribusiness through a training centre of excellence for enhancement of rural employment in Kenya

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Organic vegetable production has a low carbon footprint and is ecologically friendly. Vegetables produced organically fetch premium farm gate prices per kilogram ranging from 28 % to 71 % for different types. Regional demand for organic products is rising, but Kenya lags in organic farming with merely 37,000 registered producers. The number is lower compared to the neighbouring countries' statistics i.e., 210,000 (Uganda), 204,000 (Ethiopia), and 149,000 (Tanzania). Large-scale organic farmers in Kenya have contractual agreements with private exporting companies and get certification using international organic standards e.g., Bio Suisse. However, most smallholder vegetable farmers remain in conventional farming because of the costs associated with certification. The problem calls for a panacea to revolutionize smallholder vegetable production from conventional to organic enterprises and provide links to local and regional markets. We propose a project called Enhancement of Rural Employment Through Organic Vegetables (ERETOV). The project shall mainly promote the production of the most demanded organic vegetables in the main markets of Nairobi and the East Africa region. The project shall start by improving an existing training facility at the Africa IPM Association (EIPMA) to serve as a training centre of excellence in organic farming. Capacity-building among smallholder vegetable farmers will be conducted at the proposed centre. We shall organise farmers into producer groups through participatory guarantee systems (PGS) that will be supported by the Kenya Organic Agriculture Network (KOAN). Through PGS, KOAN will link farmers to the local and regional markets. The project will increase opportunities for rural employment creation through the development of future agribusiness entrepreneurs. For project sustainability, the implementing organisation (EIPMA) will have a licensed nursery of organically propagated vegetables where farmers can access their seedlings after the end of the ERETOV period.

Keywords: Center of excellence, organic farming, rural employment, vegetables

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Challenges of nitrogen production fertilisers from renewable energy for farmers

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Every year countries all over the world produce millions of tonnes of the three essential nutrients nitrogen, phosphorus, and potassium, which plants need to grow to their full potential, and for this production, they use natural's raw materials such as air, natural gas, and mined ores.
Nitrogen-based fertilisers account for the vast majority of fertiliser use, and these types of fertilisers need a high energy consumption and specific condition of high pressure and temperature.
For this purpose, an alternative of producing nitrogen fertiliser with low energy consumption and with low carbon emissions will be a great challenge and will help farmers to improve yield production. Nitrogen fertiliser based on renewable energy with the application of plasma-activated water (PAW) represent a green production of fertiliser without the need for specific conditions of temperature and pressure
The ammonia industry uses intensive energy-consuming 8MWh per tonne of ammonia with higher dioxide carbon emission 1, 6 tonne of CO_2 per tonne ammonia with the natural gas source without cunting the transport emission, but with the technologies of plasma-activated water will be zero carbon emission, from water, air, and renewable electricity to produce nitrate NO_3 directed used in irrigation.
With this technology, the implementation of the system in the field of farmers will make them produce their fertiliser using clean and green resources and nitrogen is not available where it is needed most without transport cost. Also minimising the environmental impact of the gas emission of production, distribution, and application of nitrogen fertilisers.

Keywords: Agriculture, farmers, fertilisers, nitrogen, plasma-activated water

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Utilisation of banana pseudo-stem for employment and income generation in western Kenya

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Majority of smallholder farmers in Kenya have shifted from conventional cash crop production to banana farming due to its high nutritional value. Previously, bananas were considered a semi-subsistence crop, but the shift into commercialisation has attracted many smallholder farmers to transition into commercial banana production. This makes it a source of income, nutrition, and food security. Almost all parts of the banana plant can be utilised i.e. the fruit consumed, leaves used as animal feed and processing food and flowers cooked for medicinal purposes like managing diabetics. Pseudo-stem, the focus of this project, transports nutrients from the soil to the fruits. However, this part is often underutilised and usually treated as waste. The stem is usually cut and becomes waste biomass during harvesting yet it can be used as pulp and raw material for paper and fibre for textiles. For every ton of banana fruit harvested, approximately 4 tons of biomass waste is produced, including the pseudo-stem. These are disposed into lakes and rivers or simply burnt producing harmful gases in the environment. Due to the harmful effect of the plastic bag on the environment and consequent government ban on plastic bags in Kenya, pseudo-stem fibre can be processed into re-usable carrier bags which are eco-friendly, and the resultant slurry waste is used as manure on the farm. Therefore, the project aims to propose and establish a processing plant and capacity building using a circular business model that can be implemented in some selected rural communities in Western Kenya. Currently, banana production is estimated at 1,856,659 tons, comprising over 400,000 smallholder farmers. Using a decentralised sourcing technique, this project focuses on promoting community-based enterprises. With the current poverty level being 12 % in Western Kenya, the realisation of this project idea will allow double income and employment among youth and women consequently improving their livelihoods through utilising the waste for the production of environmentally friendly bags.

Keywords: Banana, circular model, eco-bags, employment, income, Kenya, pseudo-stem

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Introducing modern beekeeping technologies at monasteries in east Gojjam zone of Amhara regional state, northwestern Ethiopia

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The overall objective of this project is to implement Modern Beekeeping Technologies in East Gojjam Zone, Ethiopia. Beekeeping provides off farm employment and income-generating opportunities through organising jobless urban and landless rural farmers, youth & women. It is also environmentally sustainable activity by conserving the forest resources via the mutual benefit of the honeybee from the nectar and its cross pollinations. Ethiopia, as located in the horn of Africa, it has a huge potential for beekeeping because of its endowment with diversity in climate, bimodal rains and forest resources that potentially favours them. There are over 7000 various plant species suitable for honey production in Ethiopia. The country has a potential to produce 500,000 tons of honey production annually. However, the production is limited only to 43,000 tons. This huge gap is mainly due to the traditional production system in the country which results in low productivity (FAOSTAT, 2015); (Kenesa T., 2018). That is why the project is initiated to establish apiary within monasteries. Monasteries are independent religious institutions in which monks, priests, and socially disadvantaged groups like land less people, women, pro poor's, and internal migrants are living together as a community having their own livelihood activities such as group farming, animal husbandry, beekeeping, handicrafts, domestic work, bookbinding and teaching. Besides, forest conservation around monasteries helps to provide grace for itself and sweet aroma for honeybees. Further, monastic communities have influences on the surrounding society through their religious education and socio-economic demonstrations for achieving the intended project impact of enhancing sustainable development.

Keywords: Beekeeping, modern technologies, monastery, sustainable development, traditional technologies

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Organic fertiliser production for rice farmers in Benue state, Nigeria

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Rice production is known to contribute significantly to food security in many African countries including Nigeria as it is a major staple food. Nigeria is the largest producer of rice in Africa with a production output of about 8,435,000 tons annually. Rice is cultivated in almost every state of Nigeria with Benue as the second largest producer. An important factor affecting rice production in Benue is the gross insufficiency of quality fertiliser. The problem of fertiliser scarcity and unaffordability by rural rice farmers threatens their economic livelihood and national food security. Meanwhile, there is abundance of organic waste materials from households and livestock that have not been well harnessed which creates an unhealthy environment in Benue state. Processing these wastes can yield quality organic fertilisers needed by farmers to boost production. In the light of this regard, this project idea aims at processing and supply of high quality pelleted organic fertiliser from household waste and animal droppings. This will be achieved through partnerships with stakeholders like livestock farmers in the region and waste management authorities to ensure the sustainable collection of organic waste, decomposition, pelleting, packaging and marketing to rural rice farmers. The realisation of this project will improve food security, increase income of rural rice farmers, create employment among the youths and women, and most importantly lead to environmental, social and economic sustainability.

Keywords: Animal droppings, environmental sustainability, food security, household waste, organic fertiliser, rice productivity

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Analysis of the tomato value chain for potential product certification and international trade

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Tomato is one of the important vegetables in Malawi grown throughout the year for revenue generation and consumption. The entreprise is dominated by poor-resource smallholder farmers who cultivate on gardens, and relatively advanced semi-commercial farmers who practice protected cultivation (Nyondo et al, 2018). However, there is an advantage to most farmers in Malawi because most of the tomatoes produced use organic farming methods which are on high demand in national and international markets.

To improve farmer's resource base, smallholder tomato farmers get organised in groups by support of other external actors i.e. non-governmental organisations and resulted into a rise in yield per hectare from 627.3 to 684.25metric tons in the years 2019 and 2020 respectively and the trend continues due to these initiatives.

Among many challenges, 80.4 % of the farmers are encountering post-harvest losses due to the perishability of the product and lack of competitive markets for fresh tomatoes (Malidadi et al, 2022). Such may restrain Malawi to be among those countries that will attain the aspirations of the African continent's Agenda 2063, particularly the aspiration of "a prosperous Africa based on inclusive growth and sustainable development".

Despite the opportunities in tomato value addition, farmers lack enough equipment and knowledge on certification of tomato processing in order to penetrate the commercial formal markets hence important to empower the farmers for increased profitability through tomato value addition and access to national and international market. This project will be helpful for the farmers to produce value added products that meet export quality.

Keywords: Certification, commercialisation, tomato value addition

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Promoting vermicomposting to enhance sustainable agricultural production

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Global population increase and climate change pose enormous pressure on the existing food systems. On the other hand, an increase in per capita income has led to lifestyle changes towards a preference for high value organic and natural cosmetic products. The aforementioned scenario call for the adoption of novel and climate-smart innovations in the development of food and cosmetic systems. Heliciculture or snail farming is an emerging and promising farming that presents a greater potential for agroecological farming and bioeconomic business model. The snail value chain presents a lucrative agribusiness that can significantly contribute to poverty alleviation and nutrition security in sub-Saharan Africa. Snail meat contain approximately 60 % protein with by-products that include slime and calcium carbonate. The slime that is harvested from snails is an important ingredient in the production of cosmetics. Furthermore, the snail shells contain calcium carbonate that is can be used in the manufacture of animal feeds and liming of fishponds. Despite the economic, environmental, and social benefits of heliciculture, the lack of awareness and research has delayed the adoption of snail production and utilisation. Therefore, the main thrust of this review is to present in summary the potential of the snail value chain for economic development in sub-Sahara Africa. The review will focus on analysing the potential benefits, systems of production, associated risks, and future outlook when fully adopted.

Keywords: Organic fertiliser, sustainability, vermicompost

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Production and nutritional analysis of improved baby food (Tom-Brown)

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In Nigeria, cereals are the major food source for weaning and growing children. Nevertheless, the level of nutrients in the commonly consumed traditionally prepared children food are significantly lower which makes it almost impossible for growing children to meet their daily nutritional requirements. The processes involved in the domestic production of Tom-Brown are tedious and requires a lot of time, this has been the major constraint for working mothers living in the urban areas of the country. Also, some mothers do not have the idea that such a highly nutritious meal exists. This has led us to the situation in the country with the following statistics; 32 % of children below 5 years suffer from stunting, 29 % of children are underweight, and 2 million children suffer from SAM.

Tom-Brown is a processed cereal-based blend which is cooked into a semi-liquid food for children especially from 6 months, which contains good levels of carbohydrate, protein, fat, vitamins, minerals and fibre. This meal is prepared by few mothers in Nigeria with grains such as maize, soybeans, groundnut, sorghum, millet e.t.c. T he grains used depends on availability, allergy, ease of handling and the financial capability of the household. Nevertheless, a widely accepted blend on the basis of nutrient adequacy consists of all the aforementioned grains which could be in different ratio depending on individual choice. This project seeks to achieve the best cereal combination ratio that would give the consumers, especially children, the daily required nutrient for proper growth and development.

Keywords: Cereals, children, food, grains, growth, health, legumes, malnutrition, Nigeria, nutrition, processing, stunting, Tom-Brown, weaning, wasted weight

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Nutritional, functional and consumer qualities of composite wheat bread with bambara nut and vitamin A fortified cassava flour in Nigeria

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Bread is an important staple food mainly from wheat flour, water, yeast and salt the consumption of which is becoming steady even in the rural areas in Nigeria. It is however expensive, being made from imported wheat that is not cultivated in the tropics.
Cassava is the third most important source of calories in the tropics, after rice and corn. Nigeria is the leading producer of cassava. High quality cassava flour (HQCF) has been examined as a local alternative to wheat flour. The yellow flesh cassava variety contains about 100 times more β-carotene than the white variety thus a prominent source of Vitamin A.
Bambara nut is a leguminous crop of African origin and considered a complete food because of its reasonably high protein content and its good balance of essential amino acids. It has the potential to serve as an ingredient for food fortification due to its affordability, versatility, nutritional quality, and sensory acceptability.
In the quest to maintain a healthy lifestyle, people are intentional about what they ingest. The objectives of this research is to develop an optimised and acceptable bread recipe from wheat, HQCF and Bambara nut flour blends with a high nutritional profile, conduct a consumer acceptability study and promote the usage of locally processed flours thereby creating a market for local farmers of Bambara nut and cassava. This innovation shall reduce absolute reliance of bakeries on the importation of wheat flour for bread production. The satisfaction of eating healthy in a meal shall be felt.

Keywords: Bambara nut, bread, cassava, food fortification, HQCF, Nigeria

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Growth performance of african catfish (*Clarias gariepinus*) fed differently processed high quality cassava peel (HQCP)

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This study is to improve food security and remove environmental problems of excessive cassava peels and reduce high cost of fish feed. Maize is an important component of feed in Nigeria's expanding livestock sector and its demand is always increasing. Vast quantities of cassava peels produced as waste during cassava processing pose serious environmental problems hence, the need to convert this waste into high quality, valuable and economical feed ingredient. The technical and economic feasibility of the transformation of cassava peels to high quality animal feed have already been demonstrated by CGIAR scientist in 2015.

Differently processed cassava peels (soaking, boiling, autoclaving and conventional) will be used to compound fish feed to feed fish for 16 weeks and the cultured fish will be subjected to growth performance indices. Based on these results, the number of entrepreneurs in feed industries and fish farmers incorporating High Quality Cassava Peels (HQCP) in their rations will continue to increase.

Processing 14 Mt of cassava peels waste annually into about 4 Mt of HQCP and at potential market value of \$100 t^{-1}, could generate around \$400 million per annum and when substituted for maize in the feed industry, will release up to 2.5 Mt of maize for direct human consumption. This could also offer significant new income and employment to actors in cassava value chain of whom 80 % are women. Healthier and better fish feed for growth & lower production cost of fish and fish feed is expected to be produced while addressing the environmental pollution threat of cassava peels through value addition.

Keywords: African catfish, HQCP (High Quality Cassava Peels), income generation, value addition

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Developing a training concept design on milk hygiene and quality among smallholder dairy farmers in southern province of Zambia

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Milk is a highly valuable food for balanced nutrition and contributes to food security in sub-Saharan African countries like Zambia. Calcium, magnesium and phosphorus are some of the essential micronutrients found in milk. Milk production provides farmers with a continuous, non-seasonal source of income and it is the main output of a dairy farm with the farmers being the main actors at production. Despite the nutritional contents and benefits from milk, knowledge on milk hygiene is insufficient (or even absent) among smallholder farmers and their workers. Poor productivity and income losses among small-scale farmers has also been reported to arise as a result of poor hygiene practices at farm level. Additional services such as training which are essential for increased productivity and, subsequently, for the growth of the sector are scarce. Good standards of hygiene are vital for the quality of the milk and its products, as well as for the producer since the milk price often depends on quality. Product safety is important for consumers and for processing with better prices sometimes paid for safer food. Furthermore, improved hygiene reduces spoilage, udder contamination and wastage benefitting producers, traders and consumers. Therefore this project aims at developing and implementing a milk hygiene training plan for small-holder dairy producers and assesses its effectiveness in fostering a mindset change to improve attitudes and practices in Southern Province, Zambia.

Keywords: Milk hygiene, smallholder, training, Zambia

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Solutions to reduce milk wastage among small scale dairy farmers in Zambia: a case of Chongwe district

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The smallholder dairy sector in Zambia offers great potential for improvement of the milk value chain. Small holder dairy farmers produce approximately 620 million liters of milk annually and only 12 % reaches the formal channels of milk processing. However, the uncollected milk has potential to be processed into sour milk by the small holder farmers and sold in formal channels. The major challenges faced include poor processing of sour milk by farmers, poor storage facilities and irregular timing in milk delivery to Milk Collection Centers.

This project aims at improving rural livelihoods of smallholder dairy farmers in Zambia using Chongwe district as case study, by providing solutions towards milk wastage through promoting local processing of sour milk. The target small holder dairy farmers will be trained to process sour milk so that they supply to the processing industry. Benefits from this project include farmer's ability to supply fresh and sour milk thereby increasing their income. Farmer's developing new linkages in the market with other processors and farmers learning standardised milking and processing methods. The project envisages bringing different professionals from Cooperative College, GIZ, Ministry of Agriculture, Trade Kings Limited and Parmalat Zambia. This will be instrumental to improve collaboration and avoid duplication of efforts by stakeholders and will also contribute to efficient utilisation of resources. The process will follow a participatory approach to ensure effectiveness. Besides, routine monitoring and evaluation will be done and suggestions documented for annual reviews.

Keywords: Smallholder dairy farmers, sour milk, Zambia

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Sustainable pasture management: Communal paddock grazing systems to improve livestock productivity in Zambia

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Globally, overgrazing significantly contributes to land degradation, loss of biodiversity and the growing shortage of forage for livestock. In Zambia, the major livestock production system practised for ruminant animals is free-range grazing on communal land. Despite the economic and social importance of these animals, overgrazing has been a prevalent problem. The absence of a management framework of communal rangelands worsens the situation - with consequential low productivity among smallholder livestock farmers. Overgrazing is heightened in the Namwala communal grazing land of Southern Zambia due to increasing livestock population and the negative effects of climate change. To address this problem, a communal paddock grazing management system is proposed. The project aims to initiate and strengthen community-based paddock grazing systems in Namwala district. The innovation advances improvements in planning for animal feeding, soil fertility, biodiversity conservation, forage productivity, monitoring of animals for disease control and prevention. The project is intended to contribute towards improved farmer incomes through increased livestock productivity. The major activities of the project will include the establishment of farmer grazing schools, community steering board, training, mapping of forage and water and subdividing grazing land into paddocks. Furthermore, solar powered fencing wire will be used to demarcate the paddocks. To supplement seasonal animal feeding needs, higher learning institutions including vocational training centres will be engaged to develop forage-based hydroponics systems that utilises locally available materials. The project will thrive on synergistic partnerships between farmers, the Green innovation Centre, AWARE project and the Ministry of Livestock and Fisheries.

Keywords: Communal paddocks, hydroponics, overgrazing, pasture management, Zambia

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Processing and packaging of rice flour from broken rice

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Rice is one of the major staple foods in Nigeria, consumed across all geopolitical zones and socioeconomic classes. The milling process is the most important step in rice production because it determines the nutritional, cooking, and sensory qualities of crude rice. The FAO has reported that managing rice processing and the resulting byproducts into more sustainable applications would be beneficial. Depending on the strain of rice and technique utilised, up to 40 % of the yield is lost in the milling process due to the discarding of the byproducts. The byproducts of rice are broken rice, the husk, and the bran layer. Being able to utilise these byproducts in alternative industries would, therefore, improve the yield and sustainability of rice production.
After rice is polished, it is graded according to size and rice that does not meet the required size is considered broken. Medium and large rice mills generate 10 to 15 % broken kernels and this can be as high as 25 % in small mills.
This project is aimed at utilising broken rice for the production of rice flour. This will lead to reduction in competition for unbroken rice kernels, reduction in losses incurred during rice milling, improved rice production sustainability and increased food security in Nigeria. The broken rice will be ground into powder using the grinding machine and packaged in paper bags. Rice flour is gluten-free; therefore, it is an alternative for producing gluten-free products.

Keywords: Broken rice, processing and packaging, rice flour

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Contribution for small scale farmers acces to the market in Sikasso region of Mali

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Agriculture is one of the important sectors in the Malian's economy. The under-performance of the agricultural sector especially the cereals sub-sectors is due to limited access to agricultural inputs, poor post-harvest management system, poor organisation of farmers, limited access to credit and underdeveloped output markets. One of the biggest challenges for Mali is to increase cereals yields and boost farmer's productivity.

Improved performance of the agricultural sector also requires more capacity building and strengthening of producer organisations, which still lack resources and skills to support the farmers and develop the sector sufficiently. With regards to the constraints and opportunities identified and in order to contribute towards improving the income of small-scale farmers, the project intends to build the capacity of a number of cooperatives to provide adapted services to smallholder farmers and link them to buyers on contractual basis. It is well-known that agricultural markets are not self-regulating. There is no meeting point between supply and demand with optimal allocation of resources for the common good. An understanding of market demands and requirements is necessary to take advantage of market opportunities.

While important, these skills often do not go far enough in providing the specific market information required for selected value chains.

Limits and new opportunities for farmers Today, economic deregulation, population growth, urban expansion, and highly fluctuating prices (both upwards and downwards) are important factors to consider because they materially change the conditions of access to markets and marketing. (local markets, demands to satisfy, better prices).

Keywords: Farmers, market access, marketing

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Exploitation of geothermal water in agriculture (in Tunisia): Heating and irrigation of greenhouses

Faouzia Smiti

El Mandra, Tunisia

Tunisia is a country in north Africa, has many sources of energy or they are well exploited in agriculture (solar, wind, geothermal...). Agriculture is important sectors for the economy of Tunisia, where it provides the main source of livelihoods for the majority of the poor.

The use of geothermal energy ($>80\,^{\circ}C$) in Tunisia is limited to direct application because of the low enthalpy resources, which are localised mainly in the southern part of the country. In Gabes, most of the resources are utilised for irrigation of oases, heating greenhouses and used in bathing. Geothermal energy is also a prime source for heating greenhouses, soils, and water for fish farming. However, it is available 24 hours a day, 365 days a year making it more convenient to access than solar especially at higher latitudes that receive less daylight.

The geothermal water will heat the greenhouses in the cloud weather (day or night) until become 30 degrees Celsius or more, then poured into fish ponds that will be rich in nitrogen from fish waste, these waters will drain and irrigate the culture (tomatoes, cucumber, melon) to have a semi-closed circuit and zero waste of water. This commitment is based on the values of sustainable development of the three following axes: energy saving, water management, waste management.

The geothermal water is using too in bathing, and many of the geothermal manifestations in the country have the name of "Hammam" or bath. So, near the greenhouses and fish ponds there are space for camping and relax in "Hammam".

Keywords: Fish ponds, geothermal water, greenhouses, sustainable development

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Fruit tree growing programme to increase nutrition and livelihood development among rural households in Zambia

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Most rural Zambian households are engaged in subsistence-level farming that is not economically viable, often turning to unsustainable livelihoods that degrade natural resources, such as forests, to supplement their incomes. Despite more than a decade of high economic growth, most of Zambia's population remains below the poverty line with high unemployment rate among the households.
For a long time the government policies have focused more on increasing productivity among households, with a specific bias towards crops like maize, to satisfy the hunger at household and national level. Less focus has been put on increasing the nutritional status at the household level. This has resulted in high malnutrition rates and associated health conditions within the population thereby affecting the future workforce productivity.
Furthermore, many households especially in rural areas do not see the benefits of conserving non fruit trees and frequently cut them down to produce charcoal as an alternative income. This has caused vast environmental degradation and has contributed to the climate change effects and poor yields with their staple food crops such as maize.
This project will aim to promote household level fruit production and value addition so as to provide a source of nutrition, income generation and environmental conservation among households that the project will target. The project will train 1000 participants on propagation and management of high value grafted fruit trees. After that, each household will be given on average 20 fruit trees depending on the available space to plant at their plot. The participants will also be trained to add value to the fruits they will harvest as to reduce on post-harvest losses as well increase their income. Additionally participants will be supported with simple processing equipment for value addition. Data for the project will be kept on each plant planted for future impact evaluation with regards to contribution to nutritional value aspect, environmental and livelihood development among the project participants. Out of the planned 20,000 trees, 5,000 fruit trees have already been propagated. These include Avocadoes, Oranges, Lemons, Pawpaw's, Pomegranates, Mangoes and Granadillas.
Through this project, 1000 targeted households in Zambia will be empowered economically, their nutritional status will be improved, and they will contribute to conserving the surrounding environment that they also depend on.

Keywords: Environmental protection, livelihood development, nutrition

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Socio-economics

Economic potential of agroecology

Online posters

Farmer-led education on the Colombian andes: *Escuelas campesinas de agroecologia* as a social learning approach for post-conflict reconstruction

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In Colombia, nearly six decades of war have devastated the countryside, inducing land-related issues that perpetuate marginalisation of rural people. The 2016 Peace Agreement and the Integral Rural Reform offer new prospects of peace, yet reconstruction of the countryside requires broad participation of rural communities. The limited consideration of family farmers in rural processes, along with limited representation of their interests in national development plans, constrains their contributions in the socio-economic restoration of rural areas. Social movements advance agroecology in their propositional work as a framework for guiding intentional collective processes of socio-ecological transformation. Agroecology is an integrated approach for territorial management that applies contextualized ecological farming practices, which go in line with the ecosystems and traditions of rural territories. Escuelas Campesinas de Agroecología, i.e., Agroecology peasant schools, are farmer-led formative initiatives that emerge around productive, market and political processes aimed at scaling up agroecology by developing new knowledge and learning systems. By means of a systematisation of experiences from the Colombian Andes, this qualitative study investigates the potentialities of farmer-led agroecological education as a social learning strategy for empowering farmer communities and confronting current post-conflict challenges. The work of ECAs is analysed in relation to social learning theories, while the different pedagogies are scrutinized based on three identity frameworks – peasant, indigenous and proletarian. Results show that the context-specific approaches of ECAs enable communities to integrate diverse epistemological knowledge into collective learning systems and move it to a broader social context through social networks. We argue that ECAs represent a sustainable approach for transforming post-war environments from the grassroots level while facilitating the achievement of the post-agreement peacebuilding goals.

Keywords: Family farming, popular education, social movements

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Agroecological transitions: a case study of the Terra Vista settlement

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Reshaping agri-food systems requires systematic analysis and a detailed understanding of successful and failed existing examples. Agroecology is widely considered a powerful tool for transforming food systems and a key element for a growing emancipatory movement that seeks to strengthen rural people's power and control over their own production systems. Using the case of a successful transition to agroecology in Brazil, we combine theoretical concepts on rural social movements and agroecology to analyse the transition process and the scaling potential. The case study focuses on the Terra Vista settlement, located in north-eastern Brazil, and a member of the Landless Rural Workers Movement (Movimento Sem Terra - MST). The land, a former cocoa monoculture, was occupied in 1992 and the settlers pursued an industrial agricultural model, producing conventionally and consequently further degrading the settlement's environment. Faced with a moral, economic, and environmental crisis, the settlement started the agroecological transition in 2000. Our research questions were 1) how did the settlement transition to agroecology, 2) what were the main enablers and challenges in the transition, 3) how do different actors perceive agroecology, 4) does the settlement have the potential to scale agroecology. We use a qualitative case study approach and Participatory Rural Appraisal (PRA) techniques. Data collection consisted of 15 narrative interviews. To elicit the transition process until 2022, we used a time spiral. Grounded theory concepts were applied to data analysis. The time spiral showed that the transition has been a very long process in which education, collectivity and women's emancipation played a special role. Rather than being a linear process, it is cyclical and ongoing and now moves towards seeking autonomy and sovereignties (food, energy, and water). The findings show that agroecology is a way of life and a fight against hegemonic powers, rather than a set of agricultural practices. Results also demonstrated that the settlement has potential to scale agroecology, however, there is a lack of public policies promoting agroecological production and a lack of favourable markets (e.g. alternative food networks). Lastly, agroecology was crucial in overcoming a crisis, it is political and a result of the settlement's fight.

Keywords: Agroecology, agroecology transitions, MST, rural social movements

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Women's empowerment along the agriculture to nutrition pathways in a participatory community project in western Kenya

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This study is based on a participatory community-based nutrition project with the aim to diversify women's and children's diets through traditional and locally available foods in Vihiga County, Kenya. The objective of this study was to assess how the project contributed to women's empowerment, with a focus on pathway (1) agriculture as a source of food (2) agriculture as income source. To get a more in-depth understanding of where the impact occurred, women's empowerment was integrated into the analysis. The data was collected through semi-structured interviews from 25 beneficiary households in five sub-locations in Vihiga. The sample consisted of married couples. Both the husband, and the wife were interviewed (in total 50 interviews). Thematic analysis was used to determine where along the agriculture-nutrition pathways the project had an impact. The data shows that the community-based nutrition project contributed to women's empowerment along pathway one 1) women's time burden decreased as a result of men's support and involvement in vegetable production that previously was perceived as a women's task; 2) Women were able to expand their production and invested in off-farm activities such as kiosks. Along pathway two: 1) women reported that they have greater decision-making or bargaining power over expenditures as they now see themselves as providers and not dependents; 2) Women reported to be independent and rely less on their husbands to provide food for the household. At the same time husbands showed reduced responsibility to contribute to food provisioning and decision-making power over income remained dependent on who brings in the income. To maximise the nutrition outcomes and increase the impact on women's empowerment along the pathways, interventions aiming to involve both men and women from the start are needed to tackle the divide within a household and the prevailing gender norms. A household action plan may be integrated into projects to generate a common goal and vision at household level to potentially reduce the divide between men and women. A sense of togetherness could also mitigate the risk of men controlling women's income.

Keywords: Agriculture-nutrition pathways, empowerment, gender, nutrition, nutrition-sensitive agriculture

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Harmonising views of farmers and academia on paradigm shifts towards diversification in African agricultural systems

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Agriculture is one of East Africa's most important sectors, however, various environmental, socio-economic and policy related constraints inhibit its potential to meet growing food needs driven by rapid population growth and urbanisation, alleviate poverty and stimulate socio-economic prosperity. Realizing full agricultural potential will therefore require significant paradigm shifts for the diversity of sectors engaged in agriculture, nutrition and food systems. For these reasons, the DAAD Agriculture-Alumni Training Network organised a one-week travelling workshop in Kenya themed 'Paradigm shifts in Agricultural Systems towards Sustainable Land-use in Africa'. The approach was to collect and analyse views from academia, farmers and other stakeholders to identify existing and potential paradigm shifts in the context of farming systems diversity.

Increasing diversity of framing systems against principles of established industrialised food production was seen as a promising and innovative concept across disciplines and stakeholders to improve system resilience against crises and maximise sustainable agricultural production. Farming system diversification considering (among others) the application of argro-ecological principles, making use of traditional knowledge, incorporating socio-economic and socio-ecological backgrounds, and biodiversity conservation were considered superior to conventional land use concepts especially in the context of climate change. Such approaches incorporate the maintenance of ecosystems services on different spatial and temporal scales from plot to landscape level and during global change processes. Encompassed in these shifting approaches is the sustainable management of resources such as water, soil fertility, and biodiversity (e.g. pollinators). Some examples which could be better realised in diversified farming systems include the spatial and temporal integration of different agricultural production based on animals, crops or tree components in order to close nutrient cycles, integration and co-existence of wildlife habitats and food production, exploration and acceptance of alternative diets and protein sources such as insects, application of nature based solutions

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for sustainable resource use or disease and pest control, the participatory development and transfer of innovations and new technology, as well as the promotion of small scale farming, adapted agri-food networks and market access. As an emerging and promising educative approach, concrete impacts are expected in the form of professional partnerships between participants and their respective institutions.

Keywords: Africa, agricultural systems, diversification, sustainable agriculture

Bottom-up or top-down? Transitioning to agroecology

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Although agroecology has gained recognition from e.g. the IAASTD and FAO as an important solution for creating more sustainable agri-food systems, it remains a niche form of production in many countries. In Nicaragua, which has been a vanguard of agroecology since the 1970s, bottom-up processes (based in action from farmers and civil society) and top-down processes (based in government policy) have together supported the development of agroecology as a science, a set of agricultural practices, a movement, and politically. What can be learned from the Nicaraguan experience, and how can these learnings be applied in other contexts? Based on a mixed methods, longitudinal case study, this paper explores the growth of agroecology in Nicaragua and derives recommendations for supporting agroecology in other countries. Using a socio-technical lens, the paper unpacks the development of agroecology as the growth of a new socio-technical system. Based on the multi-level perspective of transitions to sustainability, an innovation history timeline was created that maps events and involved organisations and categorises these as bottom-up or top-down. While the development of agroecology is often seen in the literature as more of a grassroots-led, bottom-up process, the analysis lead to two main findings that challenge this assumption. First, the results show that in Nicaragua, the interplay between bottom-up and top-down processes has pushed the growth of agroecology. Formalized agroecology first emerged through a government-associated organisation, was later strongly supported by farmers' organisations and civil society, and is now supported by a broad cross-section of actors that initiate both bottom-up and top-down activities. Second, individuals and organisations that navigate between bottom-up and top-down spaces are central actors in supporting agroecology. Such hybrid actors are able to push for agroecology in both spheres without losing legitimacy in either. The results point to the important roles of both bottom-up and top-down processes to support agroecology, and the central functions of intermediaries in supporting transitions to agroecology. To further support the growth of agroecology in countries around the world, recommendations are derived from the case study and generalised to be applicable for policy and practice in different contexts.

Keywords: Agroecological transitions, case study, multi-level perspective

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Local agroecological knowledge and climate change adaptation in eastern Africa

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Implementation of sustainable adaptation strategies in agricultural systems requires context specificity due to varied impacts of climate change on farmers and agricultural systems. Climate change is projected to impact on food security due to changes in temperature and an increased frequency of extreme events which cause a reduction in crop yields and impacts on yield stability. In the mountain ecosystems, the complexity of the environment characterised by changes in temperature and precipitation over short distances draws the attention to the need for contextualized response strategies for continued food security. Adaptation in agricultural systems is therefore important as it determines the severity of the impact of climate change impacts on food production. In the context of African agriculture, vulnerability of smallholder farmers is a function of climate change due to reliance on rainfed agriculture and socio-economic factors such as inadequate financial resources to support adaptation, limited access to information, under-developed infrastructure and lack of supporting institutional and policy environments. Adaptation strategies that are currently being implemented are likely to be insufficient in enabling farming communities to cope with longer-term climate change. This is because these strategies are implemented using a top-down approach, without due consideration for the prevailing environmental, policy, social and economic factors within which the smallholder farmer operates. Using a mixed methods approach, this paper proposes to identify existing agro-ecological practices in a mountain ecosystem in East Africa, to determine the context in which the strategies are implemented and to identify the barriers to implementation of the identified agro-ecological strategies. We propose that integrating the local knowledge on agro-ecological strategies in adaptation planning will support the increased uptake of the strategies and promote their sustainability within the agricultural systems.

Keywords: Adaptation, agro-ecological strategies, local knowledge

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Perception and barriers to commercialisation of non-timber forest products in the Jomoro district of south-western Ghana

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The Ankasa conservation area is the most diverse forest in Ghana with about 800 vascular plant species with some species yet to be identified. People living in proximity to forest areas use forest products particularly for subsistence and commercial purposes, however non-timber forest products are more of subsistence and there exist tendencies to commercialise. Despite the potential of non-timber forest products, little is known about households' perception and barriers to commercialisation of these species. This study therefore assessed households' perception and barriers to commercialisation of non-timber forest products in the Jomoro district of south-western Ghana. The Jomoro district was purposively selected and convenience sampling was used to select 90 households involved in forest products collection in the Jomoro district namely Cocoa town, Anwiafutu, Amoakwa and Anwomakrom. The free-listing method was used to document the kind of non-timber forest products and their purpose of collection. A 5-point likert scale was used to determine the perception to commercialisation of non-timber forest products. The means were estimated from the 5-point likert scale to rank the barriers to commercialisation of non-timber forest products. The results from the study revealed that 18 species were predominantly collected. The majority of the respondents (22 %) were involved in the collection of rattan, followed by bush mango (17.8 %), bush pepper (16.7 %) and 13.3 % of forest collectors were involved in the collection of bamboo, kola and wild mushrooms. All species collected were used by households for food and medicinal purposes other than rattan and bamboo which were used for construction. The outcome from the qualitative analysis revealed that farmers had a positive perception of non-timber forest products as an alternative source of income, employment avenue for rural people, government revenue generation from NTFPs trade and it contributes to household food security. Major barriers to commercialisation of non-timber forest products were lack of packaging and labelling requirements, limited market opportunities and lack of policy to guide the use, management and development of NTFPs. The study recommends education of forest collectors on effective packaging and linking them to dominant NTFPs marketing chains to create market opportunities for their products.

Keywords: Ankasa conservation area, forest products collection, Likert scale, NFTP

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Medicinal plant use and pathways to healthcare in Idiofa, Democratic Republic of Congo

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Primary health care in the Democratic Republic of the Congo (DR Congo) mainly consists of the use of medicinal plants. Idiofa is a large municipality 469 east of Kinshasa located in the savannah, south of the Kasai River and the Congo Basin, where patterns of urbanisation and globalisation can be observed. With 61,000 inhabitants, multiple ethnic groups, religions, origins and influences are brought together, creating a diverse society. We investigated the use of medicinal plants in this urbanizing context. Our aim was to record the medicinal plants used, describe their uses and explore pathways to healthcare for residents. In addition, we tried to analyse the dynamics behind the use of medicinal plants. We conducted 30 semi-structured in-depth interviews with residents of Idiofa. The participants were selected through purposive sampling. The use of medicinal plants was recorded through free-listing, semi-structured interviews and walk-in-the-woods. Perspectives on medicinal plants were explored through semi-structured interviews. We have registered 362 applications from 103 plants. The most commonly used plants were *Carica papaya*, *Gymnanthemum amygdalinum* and *Rauvolfia mannii*. The most commonly treated diseases and conditions were gastrointestinal infections, malaria, and anaemia. The municipality of Idiofa acted as a sink and reservoir for regionally harvested medicinal plants and natural resources in general. The sources of medicinal plants were home gardens, the savannah and tropical forest. People sought information through informal networks and traditional healers. The most common diseases were treated by everyone, specific diseases and conditions (such as those allegedly caused by witchcraft) were treated by traditional healers. People had self-proclaimed skills to treat specific diseases and conditions and did so as a business. Traditional healers acquired their knowledge through intergenerational knowledge transfer, but also through hallucinations and dreams. Allopathic medicines were supposed to treat symptoms of a disease, but not the disease itself. The influence of urbanisation on the use of medicinal plants was rather than the abandonment of traditional medicinal practices, reflected in the used diversity of plants, which can be related to the emergence of a more diverse environment.

Keywords: DR Congo, ethnobotany, urbanisation

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Linkage between small scale farmers' objectives and agroecology in crop production systems of eastern Uganda

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Crop production systems in the Eastern highlands of Uganda have experienced changes due to increasing population densities and declining farm sizes. Production practices are influenced by the kind of crops grown, area allocated to the crops and distance of the plots from the homestead. The objectives of small scale farmers and their links to the use of agroecological approaches are explored to assess the importance of individual objectives in crop production decision making. Farmers' objectives were elicited using paired comparisons. The objective preferences were then identified using ranking exercises. This was preceded by converting the objective rankings into weights, which were then used in a multiple objective decision making farm model. The weights reflect the relative importance attached to the various objectives by the farmers. The three important objectives in their order of preference were 'nutrition security', 'cash income' and 'leisure'. Nutrition security in relation to crop production diversity was considered a key objective because increases in on-farm productivity relied on farmers' health and physical strength, since most of the farm labour is provided by the farmers and family members. Cash income from the sale of crops enabled farmers to purchase other foods not available on-farm. Results from the decision-making model show that cropping plans that promote better nutrition were mixed-crop systems. Besides improving nutrition, these systems improved crop productivity. Increased cash income in mixed-crop systems was largely due to crop productivity. In comparison to the monoculture systems, mixed-crop systems promoted better utilisation of the already limited land resource. The results have shown that agroecological approaches through mixed-crop systems increase crop productivity, may reduce risk and promote better food and nutrition security in farming households. Farmers consider their objectives during crop production decision making processes, and agroecological practices can be considered for nutritional security for small scale farmers. Therefore, understanding small scale farmers' decisions regarding their cropping practices is relevant in agricultural policy formulation.

Keywords: Agroecological approaches, mixed-crop systems, multiple objective decision making farm model, nutrition security

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Agricultural extension workers' job satisfaction in sub-Saharan Africa: Role of employee safety perception in Nigeria

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There is ample evidence in the literature that farmers within the sub-Saharan African (SSA) context lack access to quality agricultural extension services due to the possible low morale of extension agents. This poor job motivation among extension staff may be also connected to the extension work environment on the field with recent civil unrest spikes, transhumance-related violence and farmer-herder/pastoralist-farmer conflicts in SSA. The negative effect of these incidents, especially the farmer-herder disputes, have been felt in rural agriculture and probably on the safety of most extension workers disseminating information within the affected communities. Some studies have examined the direct consequence of employee safety perception on health, but there remains a dearth of evidence investigating the impact of employee safety on job satisfaction. Despite these complex realities, to the best of our knowledge, no empirical study has been conducted to investigate how the safety perceptions of extension workers impact their job satisfaction in SSA. We investigated the impact of extrinsic rewards on job satisfaction drawing empirical evidence from 170 agricultural extension workers in Oyo State, Nigeria. The quantitative and qualitative data were collected in 2021. We examine job satisfaction as a psychosocial outcome, using social exchange theory to predict the effect of employee safety perception on job satisfaction. Binary logit regression result shows that higher job safety perceptions increase the probability of an agricultural extension worker reporting a higher level of job satisfaction. To contribute to the advancement of social exchange theory concerning job satisfaction determinants in developing countries, we conclude with a consistency check with the theory and its implications for practice.

Keywords: Logit model, farmer-herder conflict, social exchange theory, sub-Saharan Africa

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Can domestic staple crop production meet the demand in Burkina Faso?

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Almost half of the Burkinabe population is moderately or severely affected by food insecurity. Due to ongoing armed conflicts and the outbreak of COVID-19 in 2020, the number of food insecure people is even expected to increase. Moreover, climate change further jeopardises domestic food production and thus food security. Comparing the actually supplied calories in the current growing season with those usually consumed from staple crops, allows us to provide early information on shortages in domestic cereal production. This information can contribute to increased food security and enable governments to take anticipatory actions to adjust food imports in case of expected harvest losses or ask for external food assistance.

In this session, we would like to discuss how a forecast of staple crop production can inform early warning systems of food insecurity. Based on a statistical crop model, we provide a within-season forecast of crop production for maize, sorghum and millet in Burkina Faso one month before the harvest. Moreover, we compare actually supplied calories with those usually consumed from staple crops, allowing us to provide early information on shortages in domestic cereal production on the national level.

Results show that for most years, there is a surplus in supplied calories from maize, sorghum and millet on national level. Despite sufficient domestic cereal production from these crops on average, a considerable level of food insecurity prevails for large parts of the population. This highlights the importance of a comprehensive assessment of all dimensions of food security, i.e. food availability, access, utilisation and stability, to rapidly develop counteractions for looming food crises.

Keywords: Burkina Faso, climate change, food security, maize, millet, sorghum, statistical crop modelling, yield forecasting

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Domestication of *Monodora myristica* (Gaertn.) Dunal: Assessing agroforestry and socio-economic potential in western Cameroon

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Monodora myristica (Gaertn.) Dunal (Annonaceae) is an indigenous tree species highly valued by rural households in Cameroon for its medicinal, spicy, culinary, and nutritional properties. The specie becomes more valuable and is usually integrated into agroforestry systems. However, its availability in these agroforestry systems remains less documented. This study assessed the current potential of tree diversity in agroforestry systems and the socio-economic value derived from the sale of seeds. We conducted a floristic inventory in 10 agroforestry plots of 50 m × 20 m randomly chosen in Bangoua and Batchingou villages in West Cameroon. Moreover, 15 producers or collectors in target communities and 57 traders (including wholesalers, retailers and resellers) were randomly selected and interviewed at urban markets Mfoundi and Mokolo using semi-structured questionnaires. Descriptive statistics were used to summarise the collected data. The findings reveal that among the 34 species identified in the study area and grouped into 16 botanic families, Monodora myristica was widely represented (48.50 %) in both Bangoua and Batchingou villages. The results also showed that the average biomass of seed collected was 315 kg, 875 kg, 105 kg, and 32 kg for collectors or producers, wholesalers, resellers, and retailers, respectively. The average income from 15 kg seeds ranged from US$ 24.23, 11.00, 50.86, and 33.22 on the same selling unit for producers, wholesalers, resellers, and retailers, respectively. This difference along the value chain could result from the low production of the species, the low capacity of farmers in marketing techniques, including negotiation, and their less access to adequate market information. Despite the high commercial value of seeds, promoting their growth in agroforestry systems through domestication could ensure long-term availability and conservation strategies. Local farmers could be empowered with marketing skills to enhance their income and livelihoods.

Keywords: African nutmeg, agroforestry systems, Cameroon, domestication, profit margin, underutilised tree species

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Gender and age groups forest benefits and management incentiveS in Usambara, Tanzania

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Well-managed forests in mountainous areas such as Usambara may improve community welfare and bring ecosystem services that support agro-ecological practices, for example, through increased water flow and pest control. However, the literature in Tanzania is short of evidence on the pattern of benefits flow, poverty dynamics and forest management motivation for community groups.

Based on gender (male and female) and age groups (18 to 35 and above 35) from 79 and 80 randomly selected households from villages around Sunga and Chambogo forests, respectively; the study employed income flow accounting, poverty status assessment and factors analysis to construct management motivation index.

The results indicate significant higher income share to the youth (7.2 %) as compared to older (3.4 %) household heads (t=2.3, $p = 0.023$), as well as for female compared to male headed households (t=1.85, $p = 0.07$) in CBFM (community control) regime. On poverty indicators in community based forest management (CBFM) non-timber forest income had no influence on poverty headcount but reduced poverty gap by 3 % (37.4 to 34.8 %) for youth, and 1.4 % (25.6 to 24.2 %) for older households as well as poverty severity for 3 % (19 to 16 %) for youth and 2.2 % (12.2 to 10 %) for older headed households. For genders in the CBFM, poverty gap was reduced by 4 % (64.9 to 59.5 %) for male headed households, while poverty severity was reduced by 3.6 % (28 to 23.4 %) for male and 5 % (28.3 to 22.2 %) for female headed households. The older (1.77) household heads as compared to youth (1.56) (t=2.3913, $p = 0.019$) and male (1.81) compared to female (1.64) headed households (t=2.1461, $p = 0.035$) scored significantly higher on management motivation index.

The results imply more dependency of non-timber forest products for youth and female headed households; a small proportion of forest contribution to the households' income; and income benefits may not directly translate to the motivation for the forest management.

Conclusively, forest regeneration may improve income and ecosystems services flow to community groups. Profiling community groups is needed to inform and improve motivation on forest management. More research is needed beyond Usambara to unravel community groups' dynamics on benefits flow and forest management.

Keywords: Community groups, management motivation index, NTFP, Tanzania, Usambara

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Agroecology boosts agency for reproduction goals among smallholder farmers in southeast Nigeria: Implications for food security and nutrition

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Studies in Africa have demonstrated that investing in agroecological farming practices improves the food and nutrition security of farmers. However, apart from the regenerative agronomic practices associated with agro-ecology, there are also non-market aspects such as social networking activities. The study claims that the agroecology practices are promoted and established as a result of the social networks formed by the agroecology farmers, just as the network itself is perpetuated as a result of the agroecology practices adopted by these farmers. However, literature is still silent on the important roles of the non-market activities fostered through the adoption of agroecological practices. We aim to reveal the social and household reproduction dimensions accompanying the adoption of agroecological practices in self-made farmer groups and to understand their role in ensuring food and nutrition security. In-depth interviews were conducted with 29 farmers belonging to an agroecology group founded a few years ago in Southeast Nigeria. The interviews were analysed using qualitative content analysis. Our preliminary key findings suggest that participatory agro-ecological farming creates social reciprocity among the agroecology farmers and the agency for pursuing household non-market activities which had a strong potential of meeting the food security and nutrition needs of farmers; at least in the eyes of the participants of schemes. Indeed our results point to the role of agroecology group membership on food security and nutrition through social and household reproduction, beyond the agronomic sustainable production practices adopted on the farms. This idea of analysing agroecology not only as an ecological but also as a social system provides an entry point for addressing food security challenges of farming households that do not entirely depend on the market economy. Such farming households reflect the reality of rural agrarian communities.

Keywords: Agency, agroecology, household reproduction, physical reproduction, smallholders, sub-Saharan Africa

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Assessing the sustainability of improved vegetable varieties in southern Mali: a gender perspective

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Improved vegetable varieties are expected to contribute towards higher yields and farm incomes, decrease malnutrition, and help overcome environmental production challenges. In order to achieve these goals and respond to calls for more gender equity, development interventions have long been targeting women vegetable farmers. However, little is known about gendered trait preferences and the sustainability of benefits that women and men may derive from improved vegetable cultivation. We investigated these gender differences with a mixed-methods case study in nine rural communities in southern Mali. We adopted a holistic sustainable intensification assessment framework (SIAF) that allowed us to shed light on the relations between farmers' gendered preferences for tomato and African eggplant traits and the constraining and enabling conditions in the local vegetable farming context. Results suggest that despite women's high participation in vegetable farming, their opportunities for sustainable benefits from their investments remain low. Among vegetable variety traits, women were most interested in shorter growing cycles and low susceptibility to environmental conditions and diseases, while tastier and high-yielding varieties were more appreciated in terms of sales. Such preferences can be explained by women's specific challenges in production management specifically compared to men such as low control over farm income and inputs and limited capacity to circumvent problems with water sourcing, factors which increase the chances of harvest loss. For certain steps in farmwork, in fact, women had to depend on male labour, such as pesticide application, which local gender norms regard as a man's responsibility. In contrast, men's preferences rested on traits meeting customers' appreciation, such as taste and appearance, reflecting into higher sales' prices as well as into greater income stability. We suggest that integrating breeding efforts with investigations of the enabling or constraining environment including gender norms could help genetic intensification technologies to become more sustainable and equitable.

Keywords: African eggplant, participatory varietal evaluation, tomato

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Determinants of terrestrial sand mining and its agro-ecological effects around Accra, Ghana

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Sand is a crucial resource for urban development as it constitutes an integral part of the built-up environment. In Ghana, the increasing pace of urbanisation is driven by strong population growth, job opportunities in a quickly growing industry and service sector, and several push factors which induce migration from rural to urban areas. As a result, there is high demand for housing and other urban infrastructural facilities to meet the needs of an urban population. As in all major cities of the country, the main source of sand for the construction industry is from terrestrial deposits on farmlands of the rural and peri-urban city fringes. We used a mixed methods approach to examine the scope, regulation, and organisation of sand mining activities around Accra. Qualitative data were collected from key stakeholders involved in sand mining and through observation of the mining process. Trucks delivering sand to the city were counted at seven vantage routes. Our data show that on a daily average, 765 truckloads of sand are mined at a distance of up to 60 km around Accra, corresponding to about 4.55 Mio m^3 or 12.1 Mio t or a mined area of 284.2 hectares annually. The cost-revenue structure along the supply chain of sand shows an uneven distribution of profits from this resource. While sand mining constitutes a highly profitable activity for landowners and sand miners, farmers, who are either pushed to distant locations in search for new lands or forced to give up their livelihoods, are little to not at all compensated. Illegal sand mining activities around Accra are fostered by complex bureaucratic and enduring licensing procedures, widespread bribery and corruption between miners and regulatory stakeholders, insufficient monitoring of miners, particularly at night, and short-term decisions of landowners. Even though sand mining is necessary for economic development, it puts a uni-lateral burden on local farmers and poses a threat to food security in the region.

Keywords: Natural resource extraction, sand winning, urbanisation

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Does adoption of soil conservation practices improves farm productivity and food security? Experience from Tanzania

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The adoption of soil conservation practices (SCPs) has been widely recommended by different experts as a vital strategy to address the cross-cutting problems of food insecurity and climate change. This is well reflected in the Sustainable Development Goals with special attention given to developing countries where the problems of population pressures together with growing climate change are severely impairing farm productivity and thus worsening the food security situations of these countries. However, the level (packages) of adoption and extent to which it translates into different development outcomes is not well established leading to unclear and sometimes confusing policy implications. Using the Tanzania's National Panel Survey (NPS) data for 2019 wave, we employ the Inverse Probability Weighted Regression Adjustment (IPWRA) approach to examine the determinants of farmers' decisions to adopt various SCP packages and the effect of the adoption of each package on farm productivity and households' food security. The findings show that the households' socio-economic and plot characteristics, access to mobile phones, credit, extension services and socio-protection programmes are among the key determinants of households' decision to adopt the SCPs. With regards to the effect of adoption of SCPs, we find that, on average, farmers who adopt more than one package are more productive and food secure relative to non-adopters. Our results show even stronger effect of SCPs for those who adopted all three practices (soil erosion control, fertiliser/manure application and fallowing) than for those who adopted only one or two SCPs. We therefore recommend for promotion of policies that enhance comprehensive adoption of multiple SCP packages a meaningful improvement in farm productivity and food security. Furthermore, the study recommends for promotion of SCP adoption initiatives should go hand in hand other potential policies and such as credit access, quality extension services and social protection programmes to enhance adoption of SCPs and their impact.

Keywords: IPWRA, farm productivity, food security

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Why do small-scale farmers resist change? Preliminary results from Utengule / Usangu, Tanzania

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Tanzania´s agriculture has grown rapidly over the last two decades and plays an essential role in the national economy. Despite structural shifts resulting in the increased productivity of large-scale agriculture, small-scale subsistence farmers are still the backbone of agricultural production in the country. Also, the poverty rates among the small-scale subsistence farmers are high, hence any increase in their profit has a strong poverty-reducing effect. Although government (mainly through agriculture extension officers), NGOs, and other stakeholders put a lot of effort into convincing farmers to switch to "more desirable" and evidence-based modes of farming, they often fail to make the difference. In this study, we focus on evaluating the intervention on improvement of the farming knowledge and practices of bean growers in the southwest Tanzania, that is based on the combination of training of farmers and the provision of samples of improved seeds. Members of three local cooperatives have participated in the mixed methods research (semi-structured interviews, non-participant observation, and panel study based on four waves of questionnaire). We observe various farming strategies, such as usage of recommended seeds and fertilisers, germination tests, regular spacing, etc. We explore famers' strategies and practices in three perspectives: (1) previous strategies applied before the intervention, (2) strategies planned for the upcoming season as expressed immediately after the intervention, and (3) strategies being used during the season after the intervention. Having preliminary data for one of three cooperatives, we observed that farmers have a nuanced approach to the trainers´ recommendations (some were refused, others accepted but not implemented, while the rest were accepted and implemented). Reasons for refusals and failures in implementation vary and include financial distress, labour shortage, and the unsuitability of recommendations to the local conditions. In further stages of data collection, we plan to dig deeper into why farmers do not implement recommended practices (including root causes such as demographic factors). The aim is to utilise our findings to propose efficiency-increasing changes in the intervention and curriculum of the training.

Keywords: Agricultural change, beans, intervention, small-scale farming

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Integrating livelihood, and socioecological perspectives to understand rural change: a case study in Odisha, India

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Farmers as the major socioeconomic actors in rural areas are needed to continue their life in a sustainable manner. To uncover how farmers select and shape their livelihoods and which driving forces influence them, and how livelihood change interplays particularly with broader socioecological dynamics is a crucial research topic especially in the Global South, and need more research on this area to achieve the United Nation's Sustainable Development Goals. In India, which has been rapidly developed recently, livelihoods in rural areas have been reported diversified (Majumdar 2020), and therefore variety of rural situations emerges in different places. Given the above situation, the research aims at examination of livelihoods of farm households on a case study from Odisha, India, by identifying and explaining livelihood strategies and their dynamics in their socio-ecological context in the past years. The research plans to combine the following conceptual frameworks or perspectives. A primary analytical framework is the livelihood perspective as it is an established analytical perspective used to uncover how farmers came through their livelihood pathways as micro agency. The geographical area of the case study was determined on a socioecological basis - the targeted farmers located in the same irrigation system, thereby the socioecological aspects of rural change is focused, adopting the Socioecological Systems (SES) framework (Colding & Barthel, 2019). To analyse more psychologically specific types of drivers for explaining their livelihood strategies, the theory of planned behaviour is also applied. The method of the research uses semi-structured interviews with farmers in order to shed light on causal explanation for livelihoods, strategies dynamics, decision-making mechanism. Analysis employs standard techniques for processing and analysing qualitative data, analysis also plans to combine with maps to locate the area, and direct observation of the rural settings. The result will argue nuanced situations of farmers of decision-making of their livelihoods with integration of psychological factors as well as socioecological dynamism.

Keywords: Global South, India, livelihood, psychological factors, rural development, socio-ecological framework

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Typological characterisation of smallholder silvopastoral farms in the walnut-fruit forests in Kyrgyzstan

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Walnut-fruit forests of Kyrgyzstan are a unique forest ecosystem harboring more than 130 food and medicinal plant species, many of which are endemic. This makes this forest a global conservation hotspot. More than 1 million people in this region depend on these forests for their livelihoods. However, illegal logging, overharvesting of non-timber forest products (NTFP) and overgrazing of the forest pasture negatively affect regeneration and biodiversity. To address problems of forest degradation, several protected areas (PAs) were established covering walnut-fruit forests. However, despite their protected status, these areas are still under immense anthropogenic pressure. Protected area measures that were introduced were entirely aimed on prohibiting human activities in these areas, and completely overlooked the traditional socio-ecological system based on sustainable use of walnut forests ecosystems by local households dependent on forest resources for their livelihoods. This study aims to develop an appropriate and robust classification methodology to identify and characterise silvopastoral farming systems in walnut-fruit forests to assess sustainable development pathways. Data were collected from 220 farm-households in three villages located within or in the buffer zone of the protected areas where inhabitants directly impact forests. Principal component analysis and cluster analysis were used to analyse quantitative data and aggregate farms into clusters according to forest resource availability and use, production means and socioeconomics. Three distinct silvopastoral farming systems were identified, all of which collect and sell NTFP, but also have (i) higher NTFP income, medium-sized livestock herds, and low off-farm income; (ii) moderate NTFP income, large livestock herds, and high off-farm income; and (iii) low NTFP income, small herds, and moderate off-farm income. Failure to harvest walnuts and other forest products was identified as a major problem. Overall, farms exhibited different livelihood strategies and no NTFP processing was observed in any cluster. Thus, improving forage base for livestock as well as sustainable forest grazing along with introducing new processing technologies is imperative. Use of multivariate methods identified important variables for delineating farms and subsequent clustering of farms, providing basis for further exploration of variability among farm types to target management measures for sustainable livelihoods to distinct farmer categories.

Keywords: Cluster analysis, farming-systems, non-timber forest products, off-farm

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Status quo and intensification of traditional apricot farming and processing in Gilgit-Baltistan, northern Pakistan

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Small-scale farmers in developing countries can benefit from intensification and diversification strategies by increasing livelihood security through higher income from various sources. Gilgit-Baltistan in northern Pakistan was selected in this study to reveal the opportunities and limitations of such strategies in rural mountain areas by studying the status quo of apricot production and the innovative farming practices of producers. Apricot cultivation and processing were documented and then linked to prevailing socio-economic realities. In total, 86 Households (HHs) in six valleys were interviewed. A HH level intensification index, calculated by taking the mean of seven agronomic indicators, was generated, and explanatory farm and framers' characteristics, production characteristics, knowledge, and apricot management were tested for their predictive power. The local diversity of apricot varieties was high, while the cultivation was extensive, small-scale, and characterised by low productivity. Well-adapted, local apricot trees were under threat of being neglected and replaced due to a shortage of agricultural workforce, low profits, and consecutive decreasing value attribution. Nevertheless, apricot production can contribute to the provision of nutritious fruits and increased HH earnings, as HHs applying innovative farming practices showed increased apricot incomes. The overall innovative strive among local farmers was low and decreased with remoteness from markets. Age and training were the determining factors for HHs to adopt innovations. A lack of awareness of innovative practices was attributed to slow and limited communication. Rejection of innovation was either due to low-value attribution towards apricot farming or personal objections and risk aversion. Commonly adopted innovations (e.g., sulfur drying) were either well integrated with traditional practices or characterised by low up-front costs while quickly returning benefits. To prevent the abandonment of apricot farming and the consecutive loss of associated benefits, intensively managed apricot stands need to be promoted.

Keywords: Adoption, horticulture, socio-economic, varietal richness

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An econometric analysis of gender inequalities in the cattle sector: the case of Colombia

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Cattle is the most important agricultural activity in Colombia, representing around 30.6 % of the national agricultural GDP and 19 % of the agricultural (6 % of the national) employment, surpassing the values of coffee and palm oil production by three and eight times, respectively. Despite its economic and social importance, the Colombian cattle sector is characterised by gender differences and inequalities, which are not yet fully understood. Although there exists research with both qualitative and mixed approaches, to date, there is no quantitative evidence that allows measuring the effect of gender gaps on cattle production. This research seeks to explore how gender inequalities in Colombia's cattle sector affect household production, applying a quantitative and spatial approach based on a database that combines information on cattle production, household characteristics, and multidimensional deprivation at the departmental level. Our analysis shows that only one out of four cattle producers are women, but nearly half of them are heads of households responsible for the well-being of their families. Women also participate less than men in production decision-making, tend to have lower educational levels, request fewer agricultural credits, and have smaller farms. Municipalities where there are more female producers have lower milk production and cattle inventories, which coincides with the empirical evidence for other developing countries and may originate in the difficulty of women in accessing education, financing, and land, but also in time restrictions caused by domestic work, limiting their participation in extension activities and cooperatives. Likewise, the existing gender roles burden women with unpaid care and cleaning activities, instead of the administration and commercialisation of cattle, directly affecting their ability to own cattle. Our results bring to consideration how gender gaps in agriculture, and particularly in the cattle sector, have the potential to affect national agricultural production, and with it the well-being of rural families that depend on it, highlighting the importance of policy decisions that feature a gender approach. Through an active intervention of the State, particularly through education programs, credits for rural women, awareness creation of gender roles, and land tenure/inheritance regulations, a first step can be taken towards reducing gender gaps.

Keywords: Cattle, credit access, decision-making, gender, land tenure, livestock, rural education, technology adoption

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Assessing the energy metabolism of agroecological farming systems: Understanding the role of the Ecovida Agroecology Network in Southern Brazil

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Food production remains dependent on fossil fuel-based external inputs. Soil fertility loss and global warming are some consequences of this dependency. Agroecological farming practices, such as biological nitrogen fixation and natural fertiliser use, can reduce the consumption of these inputs. Recent evidence from Brazil suggests that farming systems organised in Agroecology Networks (AEN) tend to achieve even higher autonomy and lower external input requirements because the farm-to-farm interactions create a circular compensatory movement within the components. Nevertheless, it lacks quantitative evidence to what extent the network dynamics contribute to the energy efficiency of the farms. This research gap might occur because energy assessments of farming systems commonly underestimate the energy flows exchanged within the socio-economic context. We present a conceptual framework to measure the energy efficiency of farming systems that acknowledges the interactions within AEN. We integrate two specific methods: the Agroecological Energy Analysis (AEA) and The Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM). In a case study approach, we applied this framework to farming systems of The Nucleus Litoral Catarinense, located in Southern Brazil and institutionally organised under the Rede Ecovida de Agroecologia [Ecolife Agroecology Network]. Integrating these methods is innovative because it combines the social metabolism approach with agroecological Energy Return On Investment (EROI) indicators at the farm level. Based on preliminary evidence, this framework advances in understanding how exchanged matter flows within an AEN may affect the energy efficiency of farming systems in quantitative terms.

Keywords: Agroecology, alternative food networks, energy efficiency, socio-economic metabolism

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A sustainable alternative for the Chiquitano forest in Bolivia: the Cusi palm (*Attalea speciosa* Mart.)

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Well-managed natural forests can provide multiple benefits for different stakeholders. That is the case of the Chiquitano dry forest, that for many years provided multiple ecosystem services to the Amazon rainforest and the Gran Chaco and Pantanal. Unfortunately, in the last years, this forest suffered multiple wildfires. Land use in the region is impacting the state of conservation of biodiversity and its ecosystems, particularly in the community of San José de Campamento in San Ignacio de Velasco municipality, where terrestrial ecosystems are declining due to the constant conversion of forests areas into agricultural and livestock land. This area is characterized by the abundance of some Non-Wood Forest Products (NWFPs) that involve all goods of biological origin other than wood, derived from forests, other wooded lands, and trees outside forests. One of the most relevant NWFPs in the region is the Cusi palm (*Attalea speciosa* Mart.), a native species that has multiple uses and applications. Based on these critical facts, the main purpose of this research was to analyse stakeholders' perspectives on cultivating Cusi palm as a sustainable alternative for the Chiquitano dry forest in Bolivia. The specific objectives were addressed in a three-stage approach: In the first stage, to identify local knowledge about the productive potential of the Chiquitano Forest with a focus on the sustainable production of the Cusi palm. Second, to analyse the local perspectives on the limitations and potential of the sustainable production of the Cusi palm. Finally, to identify different scenarios for the sustainable production of the Cusi palm and to support biodiversity conservation in the study area, including holistic and long-term solutions. It was found that the sustainable management of the Cusi palm with an agroecological approach could contribute to reducing deforestation, preserving biodiversity, and promoting ecologically sound, economically viable, and socially acceptable management actions.

Keywords: Agroecology, biodiversity, Bolivia, Cusi palm, noon-wood forest products, sustainable development

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Transitioning to zero deforestation cocoa supply chains: Multi-stakeholder platforms are no silver bullet

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Around the world, multi-stakeholder platforms (MSPs) have been established to solve several environmental and social challenges. MSPs are innovative and promising network governance approaches that aim to balance the interests and approaches of various stakeholders involved in complex sustainability challenges. Evidence on the effectiveness of MSPs is mixed and context-specific. Knowledge gaps remain, especially regarding the scaling potential of MSPs.
This paper aims at analyzing the governance mechanisms of MSPs involved in initiatives aiming to develop business models that are deforestation free and have low greenhouse gas emissions in the cocoa value chain in Ucayali, Peru. Therefore, fieldwork was conducted and the infrastructure of the Sustainable Amazon Business (SAB) project was used, collaborating with the International Center for Tropical Agriculture (CIAT). The paper analyses the characteristics of the different MSPs, identifying and visualizing the roles, interests, power relations, incentives and investments of different actors of the platforms. Furthermore, farmers responses as well as the functionality of the MSPs are discussed.
To allow an in depth analysis of different levels in the cocoa value chain, a comparative case study approach is used. The analysis relies on MSPs case studies: (1) technical roundtable on cocoa in Ucayali (2) cocoa association Curimana (3) cooperative Colpa the Loros, and uses different qualitative research methods for data collection, in-depth expert interviews and the Net-Map tool.
The results show that the MSPs differ in characteristics and functionality. They have been initiated either by the government, farmers or jointly farmers and the private sector. Governance challenges can be observed in the domains such as market failure, state failure and community failure. Due to a lack of funding, lack of commitment by the stakeholders and its institutional design the technical roundtable is not functioning. Farmers seem to lose "trust" in the technical roundtable as a result of the limited achievement of stated objectives. In the case of Colpa de Loros, the main success factor is the inclusion and commitment of the private sector, that is absent or not committed in the other cases. These results highlight MSP is not a one size fits all, however more participatory approaches and private sector incentives and involvement offer a potential for a best fit MSP for transitioning to zero deforestation cocoa supply chains.

Keywords: Cocoa value chain, governance, multi-stakeholder platforms, Peru

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The innovation system for deforestation-free cocoa value chains: a case study from the Ucayali region of Peru

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Cocoa cultivation is often cited as a major driver of deforestation, especially in West Africa and Southeast Asia. In the case of Latin America, the literature suggests that in Colombia, despite evidence that cocoa cultivation is not a major cause of forest loss, zero deforestation initiatives have been implemented in the cocoa value chain. However, these initiatives do not fit the local context and economic development and lack complementarity with other development efforts. In the Peruvian Amazon, CIAT-Biodiversity Alliance managed a project funded by Germany's International Climate Initiative (IKI) to develop zero-deforestation business models between 2018–2021. The project focuses on the cocoa and oil palm value chains in Ucayali, a Peruvian province with a high deforestation rate. The CIAT-Biodiversity Alliance and its implementing partner, climate focus, have developed several workshops with the objectives of strengthening the regional technical roundtable of cocoa stakeholders in Ucayali and promoting good practices in cocoa cultivation to increase productivity and reduce deforestation, such as optimising the application of fertilisers and soil amendments, the use of organic fertilisers, and the introduction of agroforestry systems, among others. Using the Q methodology and other Participatory Rural Appraisal (PRA) tools, as well as in-depth interviews, this study seeks to analyse the perspective of Ucayali farmers on the implementation of the zero-deforestation business model. In this study, the analysis was conducted partly in the framework of group discussions, in which farmers expressed, on the one hand, their concern about the loss of forests, biodiversity and its effects on the climate, but on the other hand, they also expressed their unease about the lack of support they receive from the State and their low yields, which leads them to expand their agricultural land. The first results show that farmers actively participate in the workshops and identify the lack of organic fertilisation and pruning of their crops as the cause of their low productivity. However, they reject some innovations such as agroforestry intercropping because it generates a microclimate conducive to the development of diseases. The study concludes with recommendations for future interventions in the value chain with zero deforestation.

Keywords: Cocoa value chain, deforestation, Perú, Q methodology

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Building resilient value chains after the COVID-19 disruption: Challenges for the coffee sector in Central America

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Coffee (*Coffea arabica* L.) is one of the most important global agricultural commodities. For many developing countries, coffee is the top agricultural export, accounting for a substantial part of the gross domestic product (GDP). In Central American countries, coffee is one of the top agricultural sectors. In El Salvador, Honduras and Nicaragua, coffee is the main agricultural export and second largest agricultural export in Guatemala and Costa Rica. In all countries, the coffee sector represents a main source of rural employment. The central question of this paper is how small-scale farmers in Central America can build resilience to cope with the disruptions caused by the COVID-19 pandemic and the extreme climatic which events which affected the Central American region in 2020. The impact on small-scale farmers was analysed from two perspectives. First, the immediate impacts on coffee exports from Central America during the onset of the pandemic were studied. Second, price volatility and changes which affected farmers in the subsequent harvest were analysed. Finally, options to build resilience were addressed, using the framework proposed by Béné et al. (2014), where resilience is defined as the capacity to absorb, adapt and/or transform to shocks or events, which are unexpected and have short or longer-term repercussions on the system. The analysis was conducted using secondary, qualitative data sourced from reports, expert panels, interviews, and newsletters published by Instituto Hondureño del Café (IHCAFE), Asociación Nacional del Café de Guatemala (Anacafé), Instituto del Café de Costa Rica (ICAFE), Consejo Salvadoreño del Café (CSC) and for information on Nicaragua, the reports from Latin American and Caribbean Network of Fairtrade Small Producers and Workers (CLAC) were consulted. During the first wave of the pandemic, the confinement measures did not influence the 2019–2020 coffee harvest, which was over when the first cases of COVID-19 were reported in the region. The analysis suggests that climate change impacts such as the hurricanes which hit the region had a more devastating effect. The coffee sector in Central America urgently needs to adopt strategies to help farmers build resilience to cope with climate change effects.

Keywords: Central America, climate-resilient value chains, coffee, COVID-19 impact

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Ex-ante socio-economic evaluation of small agroecological farms in Anapolis, Goias State, Brazil

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This study is based on an agro-economic and socio-environmental technical survey carried out to identify and validate technologies in agroecological cropping systems of fruits, vegetables and grains, with a view to assessing the socio-economic impact. A questionnaire - rapid participatory diagnosis (RPD) was applied to small farms linked to the Association of Agroecological Producers (APROAR), in the municipality of Anápolis and region in the state of Goiás, Brazil, in 2019. The objective was to quantify the participatory adoption of technologies in generation and increase in income obtained by farmers and their families and assist in decision-making regarding new technologies. The socio-economic data obtained in the initial phase were analysed and allowed the identification of characteristics of interest, from the profile of the producer, with information on the agroecological agricultural production in use by the producers, the nutritional aspects, management and cost of the production system, related to the sustainability of the farms. The results show a quite rational use of land and labour, a smooth generation change and family succession as well as opportunities for improvement in the modal cropping system, such as (a) the adoption of bean-maize-intercropping to improve income; (b) the use of organic compost and soil cover crops to reduce cost and improve soil fertility; (c) the mechanisation of some activities to enable expansion of cultivation area with same labour force; (d) the training and adoption of farm management tools to improve overall farm' results; and (e) training of labour force in agroecological agricultural practices to improve the cropping systems in a broader sense. With the COVID-19 pandemic, almost all farmers in the study started marketing their products using digital platforms. So, there is a potential to further develop those initiatives to improve farmers' buying and selling possibilities.

Keywords: Agroecology, cropping system, family farming, sustainability

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Urbanisation's impact on agricultural production systems, social and ecological systems, and livelihood status in Bangalore's rural-urban interaction

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Even at the global ecological scale, the impact of urbanisation on adjacent agro-ecosystems may be seen in many Asian cities. Over the last 40 years, Bangalore has been India's fastest-growing city. Bangalore is surrounded by an agricultural landscape that has evolved over thousands of years and continues to contribute significantly to the city's food supply. As a result, it is surrounded by several transition processes from rural to urban land use and lifestyles. As Bangalore approaches' megacity' status, these processes are unfolding at an unprecedented rate. The dependence of cities on their surrounding ecosystems has long been neglected and little research has explicitly addressed the changes in agricultural land use and agricultural households associated with urban expansion and their interactions with surrounding natural ecosystems. The rural-urban interface refers to the area stretched out between natural and rural landscapes and entirely human-shaped cities, with multiple gradients in physical, ecological, and social conditions. In this interface different types of transformations emerge, driven by human decisions on resources use, livelihood strategies, and public policies. In this backdrop, the purpose of the research is to learn how agricultural production systems are evolving, their ability to meet food and other requirements, how these changes affect social systems, and how social and ecological systems interact where rural and urban lifestyles, aspirations, and land use collide. Bangalore was chosen as the research region for spatially explicit, real-time monitoring and analysis of changes in agriculture related to urban expansion and their interactions with neighbouring ecosystems. The main findings revealed that, as a result of urbanisation, commercial/input demanding crops tend to deteriorate soil qualities and create an imbalance in nutrient availability. For this, the policy recommendation is to develop and promote 'Crop Specific Multi-Nutrient Mixed Fertiliser' and 'Soil test-based fertiliser recommendation,' which are critical for the long-term development of the agricultural landscape. Issues and concerns that need to be studied in depth have emerged as study outcomes that are critical for the long-term development of the agricultural landscape. In terms of household livelihood security, urban households fared better than households in transition and rural areas.

Keywords: Agro-ecosystems, household's livelihood status, rural-urban interface, sustainable development, urbanisation

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Assessing the opportunity cost of ecological restoration caused by land use/ land cover changes

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In the coastal landscapes of south-western Ghana, onshore infrastructural developments associated with the commercial quantities of oil discovery and rubber expansions on out-grower schemes have accelerated rapid land use/ land cover changes with high consequences on the ecological integrity of the landscape. This calls for an understanding of alternative land use options for ecological restoration and adapted land use planning. This study aimed to identify and analyse synergies in locally-specific land use options for ecological restoration using local knowledge and expert opinions. First, the study reviewed land use activities that provide synergies in ecological restoration in tropical regions. Further, the study tested the acceptability and applicability of the reviewed land use activities with local stakeholders to identify locally applicable land use options. Expert opinions were gathered to test the scientific applicability of identified land use options. Local and expert knowledge was gathered using surveys and workshops. Next, the capacity of identified and accepted land use options to contribute to ecosystem services (ES) was assessed in a stakeholder-based modelling platform. The relationship between identified land use options and ES capacity was assessed and results were visualised in spatially explicitly maps. Finally, the opportunity cost of ecological restoration against other land uses was assessed. The results showed synergies in identified land use options compared to trade-offs experienced in rubber out-grower schemes and onshore infrastructural development. The results addressed land use options that offer local farming needs and global ecological restoration concerns. The identified land use options are considerable land use options for policy recommendation.

Keywords: Coastal landscape of southwestern Ghana, ecological restoration, ecosystem service decline, land use synergies, socio-economic activities, stakeholder-based modelling

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Analysis of social intervention in Peruvian agriculture traditional systems

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In the last 20 years, traditional production systems have gained protection from the Peruvian regulatory framework, especially in the seed legal framework, which recognised the quality of native potato seed traditional system, in 2008.
Although the agricultural sector must lead the process as a multisector task, it is unknown how the empowerment of the topic, particularly in areas of high potato agrobiodiversity, located in the unique Peruvian area declared by FAO as Globally Important Agricultural Heritage Systems (GIAHS) in 2011.
The study analyses 05 areas in the GIAHS Cuzco – Puno corridor: the Potato Park, Andenes de Cuyo Cuyo, Collasuyo, Marcapata Collana, and Lares; which were selected according to public scientific research, traditional agriculture conservation projects, and the legal recognition for their agrobiodiversity conditions; 50 stakeholders were selected for semi-structured interviews: public government (national, regional and local), non-governmental organisations, farmers union leaders, and local conservationists. In 2020, the group International Treaty on Plant Genetic Resources for Food and Agriculture summarised the contains of the Treaty in 11 categories, 8 of these were compiled for the study: sensitisation; political participation; assistance in traditional technologies; financing; participatory research; regulatory frameworks; use of quality native seed; promotion of traditional festivities.
The study uses de ICAAP methodology to quantify results. According to the results, the public sector has a weak and temporal intervention in research and technical intervention in the traditional production (0.22 points in an interval between 0 and 1); the national sector has mainly normative and centralist participation, which is not perceived by the conservationists, who prefer a direct long term relationship with the extension agents from regional government; the recognition and the formation of local leadership is the weakest implemented right (0.12 points) and its related to the sensitisation.

Keywords: Agrobiodiversity, International treaty on plant genetic tesources for food and agriculture, Peru, traditional production systems

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Can agroecological farming feed the world: A behavioural regulation from farm to folk

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In recent decades, researchers have been directed towards factors that influence farmers' awareness of environmental responsibility practices. There is a boom in this literature for studying the role of neuronal behavioural factors. Previous academic efforts have been made to evaluate factors affecting farmers' perceptions of sustainable practices. Although farmers tried to politically create a list of behavioural factors that influence the perception of sustainable practices, their discipline was limited to researching business behaviour and communication. Though the studies till now emphasise on the adoption process, but very little is being known regarding the exit decisions of farmers. Also, most studies are based on a system that highlights a static strategy, where it is impossible to study the shifts in farmer decisions over time. Agri-environmental interventions, cognitive strategies, such as behavioural techniques, have also been used to determine the response of producers to new environmental policy design. Also, the concept of planned behaviour (TPB), which focuses on the evaluation of social intentions determinants, has been widely used to explain and forecast the possible actions of farmers concerning environmental protection measures. A significant number of TPB studies have been undertaken to tackle environmental and sustainability-related behaviours in agriculture, such as farmers 'conservation-related behaviours and enhanced grassland management climate knowledge use, the adoption of soil erosion prevention strategies, the adoption of eco-friendly activities, involvement in biodiversity initiatives and other sustainable practices. The small to a higher degree of behavioural adjustment towards organic farming in both situations could be due to the organisational effect of incentives for the development of vermicomposting pits, bio-digesters as well as technological knowledge with training and the effects of climate change in both situations, The lack of irrigation water for crops, the increased cost of fertiliser, as well as the environmental and health issues, so the preference of consumer today and high demands in markets made them shift their moral attitudes about organic farming.

Keywords: Behaviour, farmers, policies, sustainability

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Agroecological strategies among Ivorian cocoa farmers links between farm characteristics and varying ecological cultivation strategies

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Over the past decade, in West African cocoa production, efforts to deliver trainings on more sustainable production techniques have been undertaken by various public and private actors. While initially the focus was mainly on Good Agricultural Practices, agroecological elements have entered mainstream sustainability projects and respective trainings have been delivered, for instance in the frame of certification projects or development cooperation. Yet, there are still little insights on adoption rates and the reasons why cocoa producers decide to opt for agroecological practices or intensification based on conventional practices.

Focussing on the variances between different farm types and farmers' perceptions regarding most pressing challenges and difficulties with the application of training contents, this study seeks to contribute to an improved understanding of impact factors for the successful application of agroecological cocoa cultivation practices in Côte d'Ivoire. The main research questions are as follows: How do farm and household characteristics impact cocoa farmers' perceptions towards livelihood and production challenges, including the ability to adapt agroecological practices? Where do cocoa producers from different farm types see most need for change regarding sustainability interventions and in their local enabling environment? What are cocoa producers' attitudes towards ecological cultivation practices?

In the frame of accompanying research, this study investigates perceptions of cocoa farmers in five cocoa areas in Côte d'Ivoire (Abengourou, Aboisso, Agboville, Divo and Yamoussoukro) targeted by the Pro-Planteurs project. Over the past two years, these cocoa farmers receive training in Farmer Business Schools, diversification and agroforestry systems. To assess farm type differences and related impacts, focus group discussions with targeted cocoa farmers will be held as well as a participatory multi-stakeholder workshop on implementation challenges and experiences conducted. Additionally, a household survey among approximately 300 targeted cocoa farmers will be realised in order to quantity farmers' perceptions towards implementation and other livelihood challenges. Based on socioeconomic, production, geolocation, and institutional factors, the farms of respondents will be clustered by typical characteristics, in order to allow for a more nuanced analysis on how these shape the position and perceptions of cocoa farmers on challenges and project interventions.

Keywords: Agroecology, cocoa, Côte d'Ivoire, farm clusters

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Participatory governance towards diffusion of climate smart agriculture (CSA): Study from northern Bangladesh

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This research aimed to understand the planning and implementation processes of participatory governance leading to choice for diffusion of Climate Smart Agricultural (CSA) technologies; as well as how exogenous and endogenous factors affect the different action situations. The decision making theories, group approach and IAD framework were used to make a clear understanding. The research design suits a mixed method in combination of qualitative and quantitative data. Key Informant Interview (KII), Focus Group Discussion (FGD) and observation were used for collecting qualitative information, while structured interview was employed for quantitative data collection. The findings revealed different degree in the rules-in-use in the four cases. Besides these institutions, the context, climate uncertainty and community attributes such as reciprocity, mutual understanding and traditional habits play important role for choice and diffusion of CSA technologies. Among governance process qualities, the overall legitimacy and effectiveness were perceived medium to high, while transparency, accountability and equity for marginalized participants were found low to medium. Farmers concerned that effectiveness of CSA technologies were not visible in short term, but these practices have been geared to improve the adaptability and ecological sustainability for the long term. Results also showed few limitations of participatory governance process qualities, but institutional rearrangements such as farmers-to-farmer information sharing and face-to-face communication do not differ widely among four cases. The study further suggests that it is very necessary to generate and disseminate context and need based technologies through overcoming institutional shortcomings indentified here, as well as promoting governance qualities, especially more emphasizing to ensure the equity, transparency and accountability.

Keywords: Climate smart agriculture, diffusion, northern Bangladesh, participatory governance

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Collective action and institutions

Oral Presentations

Posters

The effect of dairy cooperative membership on farmers' choice of milk marketing channels: Evidence from milk producers in Rwanda

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The contribution of milk production to food security, nutrition and farmers' welfare has been documented worldwide. However, smallholder milk producers face different constraints such as high transaction costs that hinder them from getting the opportunities offered by various marketing channels. Although cooperatives play a critical role in reducing transaction costs and enhancing farmers' adoption of better farming practices, little is known on the effect of dairy cooperative membership on the choice of milk marketing channels. This paper employs an endogenous switching probit model to estimate the determinants of farmers' choice of milk marketing channels while controlling for the potential selection bias of cooperative membership. We find that cooperative membership has a negative effect on the choice of milk traders as marketing channels, along with a positive effect on the choice of both milk collection centres and other buyers. These varying effects of cooperative membership also hold for non-members had they been cooperative members. Furthermore, we find that the selling price positively affects farmers' choice of milk collection centres, but the longer distance to milk collection centres may influence farmers' choice of nearby other buyers who offer slightly lower prices. Since the milk collection centres offer higher prices to farmers and are the only marketing channels that conduct basic milk quality tests, we recommend policies that support easy access of milk collection centres and enhance dairy cooperatives' governance. This will facilitate dairy farmers' access to a better marketing channel while meeting an already growing consumer demand for products safety and quality in the food industry.

Keywords: Cooperative membership, endogenous switching probit model, marketing channel, Rwanda

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The status of women empowerment across rural-urban interface of Bangalore

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The empowerment of women has become one of the most important concerns of 21st century. But practically women empowerment is still an illusion of reality. We observe in our day to day life how women become victimized by various social evils. Women empowerment is the vital instrument to expand women's ability to have resources and to make strategic life choices. Empowerment of women is essentially the process of upliftment of economic, social and political status of women, the traditionally underprivileged ones, in the society (Rajeshwari, 2015). The present study endeavours to identify the level of empowerment of women across gradients (rural, transition and urban) of north and south of Bangalore. The study was taken up in North and South of Bangalore with total sample size of 1008. The collected information was analysed using scale developed by Savitha (2005) with suitable modification and an empowerment index was constructed by considering the variables viz., Literacy, Decision on income spending, Decision on income use, decision on income expenditure on health, decision on income expenditure on children, decision on income expenditure on food, decision on income expenditure on others, women work, status of women earning and programme beneficiary. The minimum and maximum empowerment score that could have obtained by an individual respondent was '0' and '31', respectively. Categorisation of the respondents was done based on empowerment index i.e., low, medium and high empowerment index. Results indicated that, irrespective of the gradients, more than 50 per cent and 43.61 per cent of the women respondents were belongs to medium women empowerment category in North and South of Bangalore, respectively. Finally, knowledge dimension (education or access to resources or income) plays a major role in the development of women's empowerment and freedom to take decisions.

Keywords: Decision, gradients, north Bangalore, south Bangalore, women empowerment

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Institutional and socioeconomic factors that influence irrigation arrangements; Empirical results from rural Kenya

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While irrigation arrangements differ in terms of institutional and socioeconomic characteristics, irrigation has been largely considered as unsegmented. When disaggregated, it is often limited to irrigation technologies. This study investigates the institutional and socioeconomic factors that determine irrigation and the different irrigation arrangements (public scheme irrigation arrangement and famer-led irrigation arrangement). Data was obtained from a household survey in Kenya comprising of 198 non-irrigating farm households, 89 farm households in the public scheme irrigation arrangement and 97 farm households in the farmer-led irrigation arrangement. The analysis was done via a probit regression analysis to study the factors that influence irrigation and a multinomial logit regression analysis to study the factors that influence the different irrigation arrangements. The probit regression showed that education of the primary female decision maker, renting-in land, land rental price, access to extension services, household credit access and household group membership influenced irrigation positively while age of the primary female decision maker and non-farm income influenced irrigation negatively. The education of the primary female decision maker, renting-in land, land rental price, access to extension services and household group membership influenced irrigation the farmers in the public scheme irrigation arrangement positively while the education level of the household head, age of the primary female decision maker and access to non-farm income influenced it negatively. Contrariwise, age of the primary female decision maker influenced irrigation of the farmers in the farmer-led irrigation arrangement negatively while renting-in land, land rental price, access to extension services and distance to the market influenced it positively. The analyses show that age of the primary female decision maker and access to land and extension services are critical factors affecting irrigation and irrigation arrangements and thus policy interventions targeting these factors can contribute immensely in influencing irrigation and its subsequent arrangements. However, the study clearly shows the need of specific policy interventions for the different farm households in contrast to a blanket policy that assumes that irrigation is not segmented across institutional and socioeconomic factors.

Keywords: Institutions, irrigation, irrigation arrangments, Kenya, multinomial logit regression, probit regression, socioeconomic

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How do institutional characteristics and farm location affect tea farm gate prices in Ilam, Nepal?

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Demand for organically produced quality tea is rising in all parts of the world. The Government of Nepal is aware of this trend and aims to increase the volumes and the quality of the domestically produced tea. The goal is to make the Nepalese tea sector a strong brand focusing on high-level export markets. Integration of organic certification schemes plays an essential role in this transition. Nevertheless, smallholder tea farmers struggle to raise their profitability as major tea producers in Nepal despite these governmental efforts. We used this ongoing debate as a basis for our research. Within this context, we have aimed to identify the influence of institutional variables on the farm gate prices of tea. In addition, we have revealed differences in tea farm gate prices based on the specific location of the tea farm. Emphasis was drawn on the differences between organically certified farmers and those who were not certified. Data was collected in the Ilam district in Nepal among 91 smallholder tea farmers via a semi-structured survey. We have analysed the data through basic descriptive statistics and a multifactorial regression model. Our findings show that organic certification, credit access, cooperative membership, and training participation had a statistically significant positive effect on the farm gate prices of the tea leaves in the study area. The results further indicate that farm location affects the farm gate price. Therefore, farmers should be encouraged to join local tea cooperatives and acquire organic certifications for their farm operations to increase farm gate prices. This would enable them further to support the ambitious strategic plan on tea exports commissioned by the Government of Nepal.

Keywords: Cooperative, farm gate prices, Nepal, organic accreditation, smallholders, tea value chain

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The role of cooperatives on agriculture extension process and content: a case of southern province of Zambia

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Sustainable development strategies prioritise the rural populations whose majority are smallholder farmers working under complex and dynamic environmental conditions. Smallholders require quality agricultural training and information from extension providers for sound decision making. Cooperatives are perceived to speed-up smallholders' access to such training and information. For a decade now, the Zambian government has favoured cooperatives in the process of extension service delivery, with a less coupled examination of the effects thereof. With the help of focus group discussions, and survey data from 410 farmers, comprising cooperative members (208) and non-members (202), the effects of cooperatives on smallholders' access to agricultural training and information in the Southern province of Zambia were investigated. Descriptive statistics, deductive content analysis, and ordered probit regression were employed to analyse the effects. Results from descriptive statistics portray that the public extension provider is dominant in providing agricultural training and information to farmers than NGOs and private companies. Also, leading information pathways include public extension agents, radio, and cooperatives. The number of extension contacts and the farmers' confidence in extension agents are significantly higher among cooperative members than non-members. The ordered probit regression reveals that cooperative membership significantly and positively affects farmers' easier access to agricultural training, perceived training quality, and agricultural information quality. Our focus group discussions confirm such findings and indicate the causal relationship. Other critical factors in improving the access, quality of training, and information, are a higher number of extension contacts, proximity to the agricultural extension office, gender of extension agents, and social capital. However, there is a need to further reduce farmers' proximity to extension offices by increasing the number of public extension agents while paying attention to gender dynamics. Supporting cooperatives with necessary skills essential for collective access to private extension services can also contribute to agriculture development.

Keywords: Advisory services, farmer groups, information, ordered probit regression

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Public expenditure for water facility and road transport infrastructure in Ethiopia: a comparison of impacts using an economy-wide model

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Ethiopian government is investing in a wide range of pro-poor sectors but the economic effects of public investment widely vary across sectors. With a limited public resource, public investment across sectors has to be prioritised based on their potential socio-economic contributions and/or economy-wide benefits. Therefore, the objective of this study is to compare and explore the economy-wide returns of public expenditure on water facility and energy technology (such as improved cooking stoves) on the one hand and public expenditure on road infrastructure on the other hand. The source of data for this study is the 2005/06 updated Social accounting matrix (SAM) of Ethiopia. The analysis applies the STAGE Computable General Equilibrium (CGE) model developed by McDonald (2007).

This study analyses two policy scenarios; the first scenario is an increase in the total factor productivity (TFP) of water fetching and firewood collection activities due to public investment in water facility and improved cooking stoves and the second scenario is a decrease in the trade and transport margins due to public investment in road transport infrastructure. For ensuring the comparability of the return of public expenditure, the same amount of public capital is invested in both scenarios. The simulation outcome indicates that public investment in water facility and improved stoves results relatively higher domestic production in most sectors, larger household consumption, improved household welfare and improve in the major macroeconomic indicators (GDP, absorption, private consumption, and total domestic production) as compared to public investment in road transport infrastructure. Therefore, it is helpful to explore the potential economic contribution of public expenditure across the different pro-poor sectors before launching public investment in any specific sector. This will ensure limited public budgets are appropriately invested in the sector that can bring relatively highest economic-wide benefits to the wider society.

Keywords: CGE model, Ethiopia, firewood collection, public expenditure, road transport infrastructure, water fetching

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Biotechnology, biomass, agroecology: Which bioeconomic approaches do Argentinean enterprises follow?

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The bioeconomy continues to be a contested field in the political debate. There is still no consensus on how a sustainable bioeconomy should be designed and how it could be anchored in society. The most prominent bioeconomy visions, concepts and strategies come from OECD, which is strongly bio-technology focused, and from the EU, which is more bio-mass oriented. There are also alternative concepts emerging, such as from the European Technology Platform TP Organics, which follows a more agro-ecological vision, and stresses the inclusion of different stakeholders from science, politics, business, and civil society. However, alternative bioeconomy concepts that deviate from the mainstream discourse, and are based on small-scale, agar-ecological models, are usually underrepresented in the debate.
This is also the case in Argentina, where the bioeconomy is mainly linked to genetically modified monoculture crops, intensive use of inputs, and export orientation, with a bio-technological and agro-industrial, biomass focus. This production model induced bio-technology research and innovations, such as drought-tolerant seeds and no-tillage systems, but also had negative consequences on air and water quality, land use changes, land distribution, health and employment, and on deforestation.
So far, there have been, to our knowledge, no attempts to classify bioeconomic ventures into bioeconomy typologies. Based on literature research, we extracted categories by which different bioeconomy types (biotechnology-focused, biomass-based, and socio-ecological approaches) can be distinguished. We used these categories in an online-survey with 47 bioeconomic enterprises which represent different sectors of the Argentinean bioeconomy. The novelty of this approach lies in the operationalisation of categories that characterise bioeconomic typologies and their application to the real business world. By using descriptive, correlation and cluster analysis, we discuss which kind of bioeconomic approaches can be identified in Argentina, if the approaches can be as clearly distinguished as the ideal types described in literature suggest, and how the different types of bioeconomic enterprises contribute to sustainable local development.

Keywords: Bioeconomy, entrepreneurship, local development, sustainability

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An environmental governance analysis of the Malaysian palm oil sector

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The oil palm (*Ellaeis guinensis*) is one of the most productive oil crops in the world. With 85 % of the world's production Indonesia and Malaysia are the world biggest producers. Oil palm production has lead to important rural and economic development of the two countries but has also caused social conflicts and environmental damages. Nowadays, palm oil production is characterised by different national and international policies and standards such as the Roundtable on sustainable palm oil (RSPO), the Indonesian sustainable palm oil (ISPO) and the Malaysian sustainable palm oil (MSPO). The setting of these policies and standards can be summarised under the therm "environmental governance". Often governance structures are intransparent and complex but nevertheless important to achieve a change in the palm oil sector and guide it towards a more sustainable future. The thesis aimed at conducting an analysis of the current environmental governance structure of the Malaysian palm oil sector. Switzerland was taken as a case study to understand international trade and regulation influences on the palm oil sector. A systematic literature review as well as in depth expert interviews contributed to the completion of the thesis. The results show that the role of the different actors within the palm oil sector are clearly defined. Different public and private governance structures shape the sector and contribute to its complexity. Switzerland, in these terms, reached an important historical step in adopting so-called PPM-based measures in its free trade agreement with Indonesia. However, the implementation of sustainability standards are challenging due to their voluntary character. As long as political enforcement is low standard adoption will remain low as well. An exception is Malaysia as there the MSPO Standard (MSPO) was implemented by legislation. Solutions for a promising future are needed. Harmonisation and recognition of the different sustainability standards are necessary. Double-certification of palm oil could be a solution as well as a more quality-oriented palm oil production.
However, an open policy dialogue with private and public actors involved in the palm oil sector is necessary.

Keywords: Environmental governance, Malaysia, palm oil sector

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Comparison of voluntary certificates as promoters of sustainable viticulture

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Agri-food systems are among the most significant contributors to global warming, but at the same time, agriculture is deeply affected by climate change. In addition, all sectors are forced to adapt to the new environmental conditions to maintain production and ensure its durability in the future. Furthermore, they must have reduced their greenhouse gas emissions to align within the Paris Agreement and contribute to the accomplishment of the objectives set out in the 2030 Agenda for Sustainable Development. The wine sector is one of the agri-food sectors most affected by climate change. Grape and wine production is extremely sensitive to environmental conditions and, in the worst case scenario, climate change might dramatically alter the current geography of the global wine industry.

This communication analyses - through a comparison of voluntary certificates and sustainability assessment programs across different countries - the response of the wine sector to these challenges.

The results reveal that one of the most important tools are the voluntary sustainability certificates. Parallel to the growth of other certifications such as organic or biodynamic, national and regional private sustainability standards have been created. In each country they have a different origin and evolution, but in general, all of them have in common an important participation of private sector and the collaboration between entities across different areas. Even though in their origins they were very different, a certain convergence is taking place in the last years, particularly in their environmental dimension.

Until recently, this expansion of sustainability certificates in the wine sector was more evident in the 'New World' producer countries than in Europe, where advances in sustainability were more linked to public regulations or individual initiatives, rather than to the creation of collective or standardised programs at national level.

This analysis is useful to understand the status and opportunities to promote and implement sustainability strategies in the wine sector, but also to understand the limitations and complexity of voluntary certifications to attract a large number of companies, and therefore, transform the major sustainability goals into operational strategies to the implementation possibilities of the different agricultural sectors.

Keywords: Certification, global wine-growing, mitigation, sustainability, wine

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Scaling agroecological packages for soil and water conservation in mixed crop livestock systems in Tunisia

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Soil degradation is a complex process driven by many unfavourable technical, socioeconomic, and institutional factors. Inversing the soil degradation dynamics requires an integrated approach where a set of soil-friendly, social and organisational actions within the agroecological approach are needed for system transformation. Within the GIZ ProSol project in Tunisia, ICARDA's SWC@Scale project is now piloting integrated interventions in a degraded area of Siliana governorate, Northwest Tunisia, to further enhance the sustainable adoption of a set of agroecological soil and water conservation practices in mixed crop-livestock systems. ICARDA and its National Research and Development partners are implementing a full agroecological sociotechnical package with farm and landscape interventions with forage-based crop rotations, improved grazing practices, mechanical and green consolidation of degraded land, cultivation of Sulla and Cactus opuntia in marginal lands, small-scale mechanisation, capacity development, awareness raising on soil regeneration and support of community organisations. The interventions in the selected community aim to generate system transformation dynamics and re-locate the local marginal systems on a sustainable intensification pathway. The SWC@Scale project further aims to learn from this open living lab experience and track social changes and adoption behaviour of farmers in response to the agroecological socio-technical package's implementation of the "integrated system transformation" actions. Lessons learned are shared with the PROSOL programme leadership in Tunisia for scaling. For that, the project has developed an adapted version of the scaling scan tool which explores the scope for large dissemination of agroecological practices implemented in the study area. The tool led to identify the opportunities and constraints related to the scaling of the technological packages. Notably, the crucial ingredients revealed by the tool are the level of knowledge of farmers and extension agents, the actors' collaborations (platforms), the governmental support (subsidies), and involvement and ownership by the public and private sector. The use of the scaling scan tools allowed us to elaborate a scaling roadmap showing the major activities needed to go at scale with the socio-technical packages, that can be shared with the national partners including the policy makers.

Keywords: Agroecology, scaling, soil and water conservation, system transformation, Tunisia

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Framing a conceptual toolkit for institutional transformations of Cambodian aquatic food systems

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In Cambodia, fisheries play an important role in the national economy, culture and food security via food sovereignty. The natural supply of fish and other aquatic animals from rice fields is an important contribution to rural economies and their nutritional well-being. Thus, increasing this supply captures the attention of policies and strategies targeting the Cambodian food system. In this context, agroecological interventions, such as community fish refuges, are developed as fish conservation measures that aim to improve fish productivity in rice fields. The complexity of the interactions between the numerous environmental and socioeconomic variables influencing these socio-ecological interventions requires a deeper understanding of the institutional transformations of food systems. In this sense, this research focuses on developing an analysis on collective action and governance of Cambodian inland fisheries. Our position aims to address the socio-ecological relations and power issues at the heart of a food sovereignty approach that prioritizes the need to respond to the basic food needs of local people, proposing food as a right of local communities. To this end, we develop a set of conceptual tools for the analysis of institutional transformations in Cambodian aquatic food systems. We draw on the theories of critical institutionalism to understand the institutional arrangements of aquatic food systems. We elaborate a conceptual toolkit for the governance analysis of the community-based fisheries refugee project developed by WorldFish in Cambodia. We conduct an assessment of the impact of this project on the institutional dynamics of rural communities in Kampong Thom province. Our study considers the trajectory of the project, selecting a sample of rural communities that established community fish refuges in the period 2016 - 2021, and communities that are developing the same from 2021 onwards. The conceptual model can feed back

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into existing governance models developed for the project and systems for decision support and collective action in aquatic food systems in Cambodia. In turn, highlighting the achievements of an agroecological approach project that has demonstrated a significant increase in terms of food productivity and biodiversity in the intervention areas.

Keywords: Collective action, inland fisheries, institutional analysis

The effects of agricultural programmes on the adoption of climate-smart agriculture and food security in Zimbabwe

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Predominantly rainfed farming systems have succumbed to the devastating impacts of climate change in sub-Saharan Africa and particularly in Zimbabwe. The land and agricultural productivity are below potential in smallholder areas, and these constraints are increasingly impending food security and farm sustainability achievement. Relevant policy programmes have a more significant implication underlying support to farmers in land-use strategies, adaptation to climate variability, enhanced agricultural yields, and food security. To address these challenges, the Zimbabwean government implemented the Zimbabwe livelihoods and food security program (LFSP) Pfumvudza and the Special maize for import substitution scheme (SMPIS). Therefore, the study aimed i) to investigate the farmers' perceived benefits of Agriculture input support (AIS) programs, ii) the effect of agricultural programmes on household food security, and iii) to determine the factors that affect the adoption of climate-smart agricultural practices (agroforestry, improved seed varieties, crop rotation, and planting basins). A survey questionnaire of one hundred and nine (109) respondents using face-to-face interviews was conducted in the Goromonzi district of Zimbabwe. Improved seed varieties and planting basins were the most adopted climate-smart agricultural practices, with 96.3 % and 91.7 %, respectively. Further findings indicated that improved household food consumption and increased crop yields were the main perceived benefits of the programs. The food consumption score showed that 53 % of the farmers belonged to the acceptable food security category. A binary logistic regression model revealed that participation in farmer field schools, cooperative membership, extension services, farmer to farmer, radio, years of education, and household size significantly, and positively influenced the adoption of programmes and climate-smart agricultural practices. At the same time, the male-headed households were found to be the primary adopters. It is, therefore, critical to encourage and strengthen the collaboration of local farmers' authorities and the government, in formulating, empowering, monitoring, and implementing ecological programs. Thus, promoting the adoption of a combination of suitable climate-smart agricultural practices, enhancing agricultural yields, sustainability, and food security.

Keywords: Adoption, climate-smart agriculture, food security, input support, programs, sustainability

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Diagnosing agroecosystems through interdependent networks of actors, actions and outcomes

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Scholars are faced with the challenge to explain the emergence of negative social and environmental phenomenon through numerous human and non-human components with multiple feedbacks in agroecosystems. The knowledge is lacking about how and to what extend the interaction of social actors and ecological components can facilitate or obstruct the achievement of desired outcomes in agroecosystems. This paper aims to clarify the interactions between social actors and ecological components by diagnosing the social and environmental outcomes of agroecosystems through multilayer interdependent of actors, actions, and outcomes. A prominent case is the Zayandeh-Rud river basin in Iran where its agroecosystem is crashing down due to a severe water scarcity. Accordingly, we propose a Network of Action Situations and Outcomes (NASO) framework, adapted from the Institutional Analysis and Development (IAD) framework by incorporating elements from the Networks of Action Situations approach. We used qualitative and quantitative approaches to collect and analyse data and information from primary and secondary sources related to the case of Zayandeh-Rud river basin, Iran. We collected primary data and information through field observations, five in-depth expert interview, three focus-group discussions, four interactive workshops with the contribution of 126 persons from the water, agriculture, and environment sectors, farmers, and civil society. In addition, we conducted a questionnaire-based survey (N=156) from decision makers, experts and farmers at local, district, provincial and river-basin levels. We diagnosed particular focal action situations and interdependent outcomes and actors using NASO framework. According to centrality metrics, water conflicts is the major outcome, tightly interconnected with focal action situations through feedback and impacts. Water conflicts are a growing consequence of other outcomes including inter-basin water transfer, less surface water available for irrigation, disagreement on irrigation water rights, loss to farmers' income, food insecurity, and migration of farmers to cities. We demonstrate the importance of studying interdependent networks of outcomes against the background of interdependent networks of action situations and networks of actors in agroecosystems. This study provides key concepts and findings to determine potential transitional pathways towards sustainable agro-ecological systems for addressing food insecurity and environmental degradation at local and regional levels.

Keywords: Agroecosystems, institutional analysis and development, interdependency, network of action situations, water conflicts, Zayandeh-Rud basin

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E-commerce blast to mitigate the adverse impact of COVID-19 crisis on rural agriproduct trade

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Apart from being a global health concern, the COVID-19 pandemic is having major consequences on the rural agriproduct trade in the developing regions of the world. A systematic review has been conducted to delineate whether E-commerce (Electronic Commerce) mitigate the negative effect of COVID-19 on agribusiness sectors and the necessary adjustments needed to make the E-commerce platform emerge in the aspect of rural development focused on developing countries. For the review, we used the keywords COVID 19, Developing Countries, E-commerce, Food Security, and Rural agriproduct trade were used to search research articles in the search engines Science Direct, Google Scholar and Web of Science. 105 articles were initially selected and 57 were screened covering 15 countries. The majority of the literature covered the period of COVID 19 pandemic period (2019–2022), reflecting the influence of COVID - 19 on agriproduct trade and coping mechanisms, most notably through the usage of E-commerce in the agricultural sector, in a variety of developing nations. The evidence from the articles reviewed shows that E-commerce platforms have started to emerge as a promising way to trade farm produce where there are no middlemen involved and web-based relationships are formed, and E-commerce further has the potential to make the farmer more resilient to the adverse effects of COVID 19. The COVID-19 pandemic is still unfolding around the world, it is too early to assess the full impacts of Ecommerce in the food sector. Even so, most developing countries have taken steps to ensure a continuous supply of agriproducts as efficiently as possible under these challenging circumstances. Despite the initial shocks of the pandemic, E-commerce platforms are being adopted by these countries at increasing rates. Such digital transformations in the developing world would not have been possible unless otherwise there is an unavoidable precursor as the Pandemic. Adhering to and further developing E-commerce platforms will eventually boost the economic trade specifically the agriproduct trade among developing countries and beyond.

Keywords: COVID-19, developing countries, e-commerce, food security, rural agriproduct trade

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Food entrepreneurship: What matters for success: The case of young entrepreneurs in Ghana

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Youth unemployment has become a worrying problem and a cancer in sub-Saharan Africa and has often attracted the attention of policymakers and governments in the sub-region. For most young people, entrepreneurship, particularly Agri-entrepreneurship, provides a way out of unemployment and poverty. Based on this, the focus of the study was on young people in Ghana who work in agri-food processing micro and small businesses. The study aims to identify factors that influence the success (sales growth and employee growth) of agri-food processing. A cross-sectional survey was conducted among 244 young agri-food processing business owners selected using multi-stage sampling in Ghana's Northern, Ashanti and Greater Accra regions from May to June 2021. Descriptive analysis and multiple linear regression were used to determine success factors influencing Ghana's agri-food processing businesses. The descriptive analyses show that female entrepreneurs (82 %) dominate the food-based micro and small businesses. Further, the business type is mainly sole proprietorship (81 %), with insignificant numbers being partnerships (6 %) and limited liability companies (4 %). The regression results show that access to entrepreneurship training positively affects business success in sales growth and employee growth ($p < 0.1$). Similarly, entrepreneurship experience in a similar business positively affects business success in terms of sales growth ($p < 0.1$), whereas business registration and accessing credit from financial institutions negatively affect business success ($p < 0.1$). Based on our findings, emphasis should be placed on entrepreneurship training, provision of industrial attachment for young people who wants to venture into a particular area of food processing and lastly, an essential consequence of the findings is the need for improved support for access to financial capital at a moderate rate for business growth.

Keywords: Entrepreneur, entrepreneurship, food enterprises, human capital, youth

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Economic valuation and conservation of religious festivals in Ethiopia: Contingent valuation analysis

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The study has presented an estimate of the economic valuation, socioeconomic benefit, and conservation of religious festivals in the Gurage zone. Logit model and contingent valuation methods were used. The analysis of data gathering from the nominated from four woredas is taken from 320 samples of households. The result of the logit model shows that household income, religion, household family size, household savings, household education, and bid price were highly significant at 5 %. This indicates that the study is viable within the expected outcome, a particular method for economic valuations, and no market value of diverse festivals like Meskel and Arefa. The bid price of households, head of households, and dependency ratio had a negative sign and were significant variables at 5 %. Logit model also estimated influential variables of households' income were significant determinants of maximum willingness to pay for the economic value of the festivals. Finally, the mean willingness to pay of households was also estimated and expanded into the collective willingness to pay for the protection of the festivals. The mean of Willingness to Pay (WTP) obtained from the logit model and open-ended question of the household is birr 42.7927 on average. The monetary value of no economic use-value of the festivals was also estimated by the travel cost method through consumer surplus, directly and indirectly, obtained any programme that would be designed to announce and motivate the festivals like Bazar, and prepared a joint-community involvement for its successful implementation with the government. The policy recommendations which is provided by the researcher and participant by the government are as follows. The concerned body should increase different services that are provided for the travelers. This is because the economic benefit of the festival is so important. The concerned body should have expense a higher income to support the improvement and expansion of the types and quality of the festival celebrations. No one project and tourism centre or resort are present in the zone is a headache for households. Therefore, the government should replay, the household's question and preserve Meskel and Arefa festivals, which are very important to the society Guraghe community.

Keywords: Contingent valuation method, economic valuation, Meskel and Arefa festivals, travel cost methods, willingness to pay

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Women in business in Albania

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The social and economic progress of a democratic country is based on an active civil society in which men and women can develop their capabilities on an equal footing. Albanian women have long been a part of the country's economy and social life, and have reached high levels of education. Even so, their situation is replete with contradiction Albania has become a much attractive environment for the development of women's entrepreneurship. If women are provided with the necessary resources, skills and opportunities to create strong businesses, and if they are willing to pursue the growth potential of these companies due to a more favourable environment, will benefit from economic growth.

When it comes to gender equality in Albania, mainly it is meant to advance the position of women in society. Looking at the situation of women's performance in the labour market, indicators are quite worrisome. Women are subject to a higher rate and longer term unemployment and reduced participation in the labour market (60 % of women) (LFS, 2011), whilst their involvement in private self-employment activities is lower (Miluka, 2011) as compared to men in Albania. Another feature is women concentration in sectors with low productivity and a high rate of informality, such as agriculture and manufacturing. Seemingly, they are less involved in industry and service sectors as compared to men (ISB, 2013). Such concentration is partly a result of the educational system and of women's overwhelming responsibility to tend to domestic chores.

Over 25.7 % of active enterprises in Albania in 2018 were owned or managed by women, the Institute of Statistics (INSTAT). This means that women entrepreneurship is in a proper way to grow up. Women entrepreneurs run 40,953 out of a total of 162,853 companies of all sizes across Albania. The data confirm that 24.5 % of all active enterprises began their activity before 2011. In terms of region, Tirana has the highest percentage of female entrepreneurs at 41.4 %. Most companies run by women are small-medium sized enterprises. However, 19.6 % of big enterprises, with 50 and more employees were managed or owned by women. In general, producer services prevail in the Albanian economy with 65 % of active enterprises. Over 51.4 % of producer services are based in Tirana, Durres, and Shkodra municipalities. Retail and trade account for 21.6 % of enterprises, while accommodation and food ser-

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vices account for 12.4 % of enterprises. Foreign and joint enterprises in 2018 accounted for 3.8 % of all active companies and provided 9.6 % of employment. Companies from the EU, accounted for 64.8 % of most foreign/joint ventures. According to INSTAT, companies that offer management and consultancy services are mostly owned or co-owned by international citizens. Big companies with 50 and more employees represent only 1.2 % of all enterprises. However, their contribution to employment is 48.1 %. About 89.4 % of enterprises are companies with one to four employees. The data confirm that 75.9 % are enterprises with only one employee.

Keywords: Business, entrepreneurship, labour market, women

Constraints to yam (*Dioscorea* spp) price formation in the urban and rural markets of the western agricultural zone of Nasarawa state, Nigeria

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The research analysed the constraints of yam (*Dioscorea* spp) to price formation in the urban and rural markets of the western agricultural zone of Nasarawa State, Nigeria. Well structured questionnaire was used to source for data from 200 hundred randomly selected yam marketers from the urban and rural marketers in the zone. Descriptive statistic such as frequency, mean, and percentages was used to analyse the data. The result obtained revealed that 60 % and 62.5 % were male in the urban and rural markets respectively, with the mean ages of 47 years and 43.9 years respectively. The mean household size was 7 and 6 members for the urban and the rural households respectively. Among the constraints to yam marketing are price formation, high transport cost, breakage of yam, poor and inadequate storage facilities, activities of middlemen in the markets as lack of many buyers in the markets ranked topmost in the urban and rural markets. Therefore, the research suggests a deliberate government policy towards rehabilitation of roads linking the rural and urban markets, and this may enhance trade between urban and rural markets. This will also help to reduce transportation cost and breakage of yam and thereby improving their profitability.

Keywords: Formation, price, rural, socio-economic, urban, yam

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Flood vulnerability assessment for social inclusion and disaster preparedness

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In recent years, natural disasters have claimed lives and disrupted economic and social structures in both developed and developing countries. Among natural disasters, floods and landslides have been the most devastating and recurring, accounting for 47 % of all weather-related disasters, and affecting 2.30 billion people worldwide. India is one of the regions most affected by flooding, where the frequency of floods is increasing, mainly due to topography and socio-economic conditions. Kerala, a southern state of India, has drawn attention in the recent past due to significant alterations in the characteristics of the southwest (SW) monsoon, resulting in severe flooding and landslides. Although farmers in Kerala are frequently affected by floods and landslides, there is a lack of studies on the vulnerability of farmers in these regions to floods and landslides focusing on socioeconomic aspects. Therefore, assessing farmers' vulnerability to natural disasters is a compelling action that should be taken to reduce disaster-related risks and ensure livelihood sustainability.

In this article, we assess the vulnerability of farmers in Kerala using a Societal Vulnerability Index for Floods and Landslides (SVIFL). A study that focuses on farmers' vulnerability to floods and landslides which considers their social dimension in addition to the physical, environmental and economic dimensions is important for understanding how hazards interact with individuals and communities. To develop the index and compare across regions, data were collected from 520 farm households in the highlands and lowlands of Kerala. For the vulnerability assessment, 75 indicators were selected that were appropriate for each location.

According to SVIFL, the highlands of Kerala are more vulnerable to flooding and associated landslides than the lowlands. Of the four components studied, we find that the economic component has the highest vulnerability, followed by the environmental and physical components. Surprisingly, the social component has exhibited the lowest vulnerability to natural disasters in Kerala. Therefore, the development of SVIFL can be considered as a starting point for assessing the vulnerability of the farming community, which bears the brunt of climate change and natural disasters.

Keywords: Farmers, floods, landslides, vulnerability assessment

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Agricultural development for sustainable and foreseeable agroecology in the Red River Delta, Vietnam

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This research has sought to analyse the agricultural development in the Red River Delta, Vietnam with perspectives on agroecology. The structure and emphasis of this research have been shaped mainly by the material gathered through the interviews of 234 farmers representing three farming systems (mono and poly-culture). Through the adoption of systemic approach of agroecology (objectives-practices-outcomes), this research reviews agricultural sustainability in the region. There is an existence of diverse farming systems but there is a dearth of ecological-based knowledge and practices of farm households. Whole-farm performances gained with different levels of sustainability. From socio-economic perspective, farm households achieve some profitability but less technical efficiency. From environmental perspective, there are many issues of environmental risks (spontaneous drainage of farm effluents, inordinate application of pest and disease control, unwise utilisation of synthetic fertilisers, biodiversity loss and water conflict between the 03 land-used systems).

Through rapid appraisal of agricultural information system analysis, this research identifies a vast range of constraints and their interlinked causes that hinder sustainable development. The top three clusters of constraints are mismanagement practices at the farm-scale, economic issues and environmental pollution. The first interlinked cause starts with the poor policy development associated with the limited implication of the regulatory framework for ecological-based production. The second underlying cause that influences the developments are poorly performed transferred works of advisory service providers. None of the providers achieved sustainable effectiveness. The third blocking mechanism is related to the objectives and characteristics of farmers. Most farmers enjoy their own needs of profit from farming and sell surplus products rather than feeling responsible for long-term maintenance. Whilst the conservative authorities expect both conservation and development, but it is not always possible for them to do so.

Several implications are arising to reflect on what needs to be put in place. These include ways of the policy-making process and stakeholder engagement as well as fostering of local knowledge and capacities and conservative practices in the response to agricultural development and pollution mitigation. The changes require help to regulate agriculture toward the preservation of local ecosystems.

Keywords: Agricultural development, agroecology, Red River Delta, Vietnam

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The status quo of female empowerment in the apricot sector in Gilgit-Baltistan, Pakistan

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Fostering and increasing female empowerment has become one of the trademarks of developmental work in all areas of the world. Particularly for ground project work it is decisive to know the local and cultural mechanism that hinder successful female empowerment in order to adapt and create empowerment tools that are fitted to the social and environmental circumstances of its recipients. The northern mountainous regions of Pakistan, namely, Gilgit-Baltistan (GB) have experienced a significant investment in rural development projects with many specifically focusing on uplifting women economically and integrating them through, inter alia, educational and vocational training into the economic sector of the country. In order to aid the existing developmental agencies in increasing the effectiveness of their project work of targeting rural women in agricultural settings this research has collected and analysed data through the application of the 'Abbreviated Women's Empowerment In Agriculture Index' (A-WEAI) in GB in summer 2021. This index analyses how input in productive decisions, ownership of resources, access to and decisions on credit, income control, group membership and workload contribute to the disempowerment of not yet empowered female head of households in apricot farming households in GB in comparison to male head of households. The research further compares socioeconomic characteristics of empowered and not yet empowered women in order to distinguish target areas.

Keywords: Empowerment, fruit, Pakistan, women

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Environmental education programme based on agroecological techniques to act against climate change, in Pinar del Río, Cuba

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Agriculture in its evolution towards more commercial models develops production systems based on monoculture and overexploitation of natural resources, causing negative impacts on soils, forests and biodiversity, this problem is due to the management of inadequate agricultural practices, due to the lack of environmental knowledge. For these reasons, environmental education is an important tool to develop clean agriculture based on agroecology. The research developed inserted in the DiveCropS Project: Diversifying Cropping Systems financed by DAAD of Germany try to solve the following problem: How to achieve through environmental education that rural producers adopt responsible behaviour with the environment through the use of agroecological practices? That is why the research has as its objective: to apply an environmental education Program for rural producers of the agricultural productive pole of the municipality of Pinar del Río, which allows a greater capacity to confront climate change with the application of agroecological techniques. To detect the problem, surveys, interviews and observations were used to determine the perception of producers about the existence of environmental problems on their farms and the level of knowledge in environmental culture. In the diagnosis made, 100 % of the producers perceive that the climate has changed in the region, a great concern is that they observe an increase in the salinisation of the soils and a significant decrease in yields. The applied environmental education Program manages to increase the environmental culture of agricultural producers with an important adoption of agroecological agricultural practices, with the goal of achieving real sustainable development.

Keywords: Agriculture, agroecology, climate change, environmental education

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Technology adoption and dissemination

Effects of adopting improved forages on poverty alleviation and climate risk reduction in cattle systems: Evidence from Colombia

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Cattle play an important role in rural livelihoods and the economies of developing countries, especially regarding food and nutrition security and producer welfare. Cattle support poverty alleviation by building resilience and strengthening the livelihoods of large numbers of rural people: over half a billion poor farmers depend on cattle globally. At the same time, the cattle sector is one of the major contributors to greenhouse gas emissions but is also heavily affected by the impacts of climate change, often disrupting productivity primarily by reducing feed crop and forage quality and availability as well as water availability. In this sense, introducing improved forages as cattle feed in the tropical cattle systems has demonstrated a significant reduction of climate change-related risks on cattle farms, such as reduced feed insecurity during dry seasons and reduced enteric fermentation, ultimately improving producer welfare and reducing poverty. This study aims at measuring the impacts of adopting improved forages in cattle systems in three Colombian cattle regions: Caribbean coast, Orinoquia, and Amazon. We use propensity score matching to assess the contribution of improved forages on producer welfare progress out of poverty index (PPI) and household dietary diversity score (HDDS)). The analysis is based on primary data obtained through a multistage sampling procedure with 1,039 cattle households in the study regions. Our results show that the expected probability of falling under the different poverty lines is being reduced by 2 to 7 % among the adopters of improved forages. Regarding the HDSS indicator, no significant differences were found between adopters and non-adopters. The variables cattle herd size, total farm size, pasture management, and membership in a farmer association are significantly related with the adoption decision. The results suggest a causal relationship between the adoption of improved forages and poverty reduction. These findings contribute to the roadmap of sustainable intensification of cattle systems in Colombia and highlight the need for increased investments in the dissemination of improved forages and the design of incentives that help to foster adoption levels, taking advantage of potential synergies among the agendas of cattle transformation and poverty reduction among in the cattle sector.

Keywords: Climate change, improved forages, livestock, poverty reduction, resilience, sustainability

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Genebanks and marginalised groups - how do CGIAR genebanks integrate the needs of marginalised farmers?

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Agrobiodiversity is crucial for food security and climate change adaptation. Further, plant genetic resources for food and agriculture have great cultural and economic value. They can be conserved *in situ* on farmers' fields and *ex situ* in genebanks, or by dynamically combining both conservation methods. The largest and most frequently accessed network of global *ex situ* collections was created by the CGIAR genebanks, which safeguard cultivated plants and crop wild relatives. Smallholder farmers have been growing, selecting, conserving, and exchanging crop diversity since the beginning of farming, and such diversity is crucial for their food, nutrition, and livelihood security. Additionally, smallholder farmers play a major role in the provision of food for a growing world population and have significantly contributed genetic resources to the international collections of the CGIAR genebanks. Nevertheless, only 10 % of the germplasm held in CGIAR genebanks has been directly distributed to farmers. Most germplasm of these genebanks is received by agricultural research institutes, universities and national genebanks. Smallholder farmers are often marginalised and lack access to suitable and healthy plant genetic resources. Based on expert interviews and literature research, this analysis explores the needs and priorities of marginalised groups with respect to plant genetic resources, and how genebanks currently integrate these in their projects and strategies. Further, this research explores how genebank activities can be more inclusive to improve food security, climate change adaptation, and diversity conservation in the future. Thereby, the focus is on CGIAR genebanks and how their activities integrate the needs of women, youth, and indigenous groups.

Keywords: Adaptation, agriculture, agrobiodiversity, CGIAR, climate change, conservation, culture, food security, gender, genebanks, indigenous groups, marginalised groups, plant genetic resources for food and agriculture, smallholder farmers, women, youth

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Socio-technical challenges of the implementation of small-scale biogas technology in rural areas of Cameroon

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The implementation of biogas technology in Cameroon is still low, with less than 1 % realisation of the available potential of household biogas plants. Consequently, rural households are still dependent on highly polluting energy sources such as firewood and charcoal. This study identifies the socio-technical challenges of implementing biogas technology and draws on the effects of these challenges to identify future perspectives for wider adoption and diffusion in rural households. Firstly, socio-technical problem analysis is performed in three stages; i) identifying the challenges in performing actions that lead to the implementation of technology, ii) exploring social and technical practices of various stakeholders, and iii) identifying the reasons of stakeholders for not adopting the practices. Secondly, the effects of these challenges on the implementation outcomes of the technology are deduced. Data were collected through content analysis of documents, a survey of thirty users of biogas technology (randomly selected from the West, Littoral, Central, Adamaoua and North regions of Cameroon) and observation of the production and utilisation practices. The results reveal that the rural biogas system is still poorly structured, with several social and technical challenges. The key challenges of the respondents include inadequate institutional support (83 %) and knowledge sharing between biogas users (71 %). Other challenges are low financial capacity (91 %) caused by poverty, low involvement of women (23 %) and biogas skills development (52 %). Another practical issue is the overdependence on firewood, caused by the culture of 'gathering' firewood from tropical forests, which is usually cost-free. These challenges have reduced the trust and motivation of rural dwellers to adopt and diffuse technology. Sustainable action is required to ensure the adoption and diffusion of the technology. This can be made possible by creating technical and social niches to address the challenges that affect the implementation of technology.

Keywords: Adoption, biogas, Cameroon, diffusion, energy, niche, socio-technical

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Push-pull technology as a climate-smart integrated pest management strategy in southern Ethiopia

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Push-pull technology (PPT) is developed for integrated pest and weed management in the smallholder farming systems of sub-Saharan Africa. There are several studies that document the agronomic benefits of PPT at the experimental level. However, rigorous evaluation of the technology in abating losses and increasing maize productivity outside of the experimental context in western Kenya is yet to be made. The objective of the study is to estimate the impact of PPT on insecticide use, production losses, and maize yield using data from southern Ethiopia. The study aims to contribute to a very few but emerging literature on a broad range of agroecological strategies for controlling pests, such as push-pull strategies in sub-Saharan Africa. By exploiting plot-level variation in PPT adoption among maize farmers in southern Ethiopia, we estimate the effect of PPT on production loss, insecticide use, and maize yield using correlated random- and fixed-effects regression models. We use comprehensive household (1,181)- and plot-level data (2,135 plots) to control for plot-invariant unobserved heterogeneities that may drive adoption decisions of PPT and yield losses and insecticide use. We find that PPT reduces maize production loss by about 11–19 %. We find no statistically significant effect of PPT on insecticide use. This is because farmers and the local government were in panicking mood due to the arrival of a devastating new pest called fall armyworm and indiscriminately applied insecticides regardless of PPT adoption, which is supposed to reduce insecticide use. Our results further show that PPT increases maize yield by 12–16 %. The findings suggest that PPT can contribute to food security by enhancing farmers' resilience to shocks due to pests.

Keywords: Fixed effects, insecticide, maize yield, pests, push-pull technology, weeds, yield loss

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Let's agree to disagree. Female influence in household decisions and adoption of modern wheat varieties

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Dynamics in intra-household decision making are often neglected when studying the adoption of agricultural innovations. Also, agricultural extension systems tend to address male farmers when promoting agricultural technologies. However, households' farm management choices frequently result from negotiations between female and male farmers, which differ in terms of individual bargaining power and personal interests. A better understanding of the linkages between gender roles in decision-making and related household adoption decisions could enhance the efficiency and effectiveness of public extension systems and uptake rates of modern innovations in smallholder agriculture. In this study, we use survey data from 1088 wheat producing households in Ethiopia to analyse the linkages between female bargaining power in household crop farming decisions and the uptake and turnover rate of recently released wheat varieties. We proxy female bargaining power by the levels of her partaking in household crop variety decisions and agreement between spouses thereon. In contrast to most quantitative studies analyzing technological change, this study relies on a survey that was addressed separately to female and male household heads from the same household, allowing to capture different perceptions on intra-household decision making, as well as perspectives on wheat variety choice and seed acquisition channels. To account for observed and unobserved heterogeneity that may simultaneously influence the level of bargaining power of the female household head and the decision to adopt modern wheat varieties, we employ Inverse Probability Weight Regression Adjustment (IPWRA) and instrumental variable estimators for robustness checks. Results suggest that an increased level of female influence in household crop choices is positively associated with the adoption dynamics of rust resistant varieties and decreased varietal age. We conclude that dynamics in intra-household decision making may offer valuable insights for designing and implementing strategies to enhance the uptake of agricultural technologies among smallholder farmers.

Keywords: Adoption of modern seeds, Ethiopia, gender, intra-household decision-making, wheat production

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Cattle ranching in Colombia: a monolithic industry?

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The Colombian cattle sector on the one hand contributes to the rural economy and producer welfare but on the other hand is one of the main contributors to climate change and environmental degradation. Given this panorama, the sector is currently under transformation towards more sustainability, including both climate change mitigation and adaptation. One solution for achieving sustainable intensification is the implementation of sustainable, forage-based cattle production systems. Despite the availability of sustainable technologies and practices, adoption levels are low, however. This study analyses literature on the history of cattle ranching and agricultural innovation adoption in Colombia to understand how cattle production systems have evolved from the 1950s until today. Departing from new scholarship that has questioned the idea that cattle ranching has been only a land-grabbing strategy dominated by few elites, this article focuses on the adoption of improved pastures and the role of key institutions in the transformation of practices and the shortcomings of technification. It shows that Colombia has had big transformations with the introduction of improved pastures, particularly *Brachiaria* spp., but these transformations did not translate into a radical change in the dominant extensive livestock production systems. Instead of promoting intensification, the adoption of *Brachiaria* has allowed producers to expand more, often resulting in high levels of deforestation. One of the main contributions of this article is the analysis of economic, developmentalist, and institutional reports that are not often used to construct historical analysis. It can also serve to scholars interested in the adoption of agricultural techniques.

Keywords: Adoption, climate change, deforestation, improve forages, resilience, sustainable intensification

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Improved pastures and some challenges of agricultural innovation adoption

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Since the 1960s, but more intensely since the 1980s, the factors affecting agricultural innovation adoption in the so-called developing world have puzzled scholars and development institutions. Although early studies recognised that adoption is affected not only by the promise of economic profitability but also by other attributes of the innovation, such as compatibility, complexity, trialability, and observability, economic analysis that barely touched upon sociological factors or the non-contingent character of extension programmes dominated the literature until recent years. Scholars and institutions have analysed both external factors such as credit constraints, risk, and information or internal constraints such as farm size, farmer behaviour, and land tenure patterns, showing how these factors affect agricultural innovation adoption. Yet, even when constraints are lifted or improved, adoption does not seem to increase in overall terms. To explain so, new constraints have been researched, such as gender, age, and belonging to a social network but the answer is still elusive. This study reviews and summarises evidence on experiments of agricultural innovation adoption, particularly those related to improved pastures and forage seeds in the Global South. We found that, first, farmer's social and cultural constraints must be properly mapped to explain, more in depth, the limiting factors to diffusion and the shortcomings of adoption incentives. Second, we found that perfectible transference strategies lay at the core of agricultural technology adoption, and thus we aim to amplify the debate onto how to map societal constraints and how, if so, new narratives and mechanisms should be put in place to achieve more successful innovation processes.

Keywords: Adoption barriers, climate change, deforestation, improved forages, resilience, sustainable intensification

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Actors, networks and platforms for the promotion of agroecological practices in Burkina Faso

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In the last decades, agroecology (AE) has developed from a science on the pure ecological interactions in agricultural systems, to agronomic recommendations through specific practices that utilise these ecological interactions and finally into a social movements covering also issues such as food sovereignty and farmer autonomy. Each region has its different perceptions, experience, focus of agroecology and how it should be implemented. Besides, it is not clear, which actors, networks and platforms are involved and what services are mobilised including their quality.

Within the context of the project FAIR Sahel (Fostering an Agroecological Intensification to improve farmers' Resilience in Sahel), we identified the relevant knowledge and service actors, organisations and stakeholders involved in the promotion and implementation of AE in Burkina Faso. We carried out a literature review and realised a stakeholder workshop focussing on AE knowledge and information systems within two contrasting regions in Burkina Faso (North and Southwest). In a stakeholder mapping exercise, we characterised the linkages (dynamics) between AE actors with focus on: 1) type of linkages (service or policy linkage), 2) quality of linkages (e.g., collaboration, competition), and 3) magnitude of linkages. Besides, we identified AE policies and programmes in Burkina Faso. The results showed spatially contrasting AE actors, networks and platforms across the two regions. Reasons for differences were partly caused by the climate, soils and the different crops grown in each region (cotton vs. cereals such maize and sorghum) creating different agronomic patterns as well as marketing and support structures. Overall, the local conditions lead to a higher appreciation of AE in the Northern region. These findings contribute to specific AE actor-network images for the regions and eventually for the entire country, allowing for a spatially targeted, case-specific promotion of agroecological practices.

Keywords: Agroecology, AKIS, Burkina Faso, innovations

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Adoption of technologies to increase the resilience of smallholder farmers in Zambia

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Smallholder farmers are facing various challenges related to climate change. Low productivity, and food insecurities are on the rise due to crop failure, mainly caused by floods, drought, and pests. The soil and land are in a deplorable state. Climate smart agricultural technologies (CSAT) such as conservation farming has been introduced to the farmers by both the public and private sectors. But to what extent have these technologies enhanced resilience, improved agricultural productivity, reduced food insecurities, increased household incomes, and the continued support for rural livelihoods, remains the question? I intend to investigate the CSAT promoted and practised by the farmers and how the knowledge transfer has been executed by the public sector, private sector and the civil society as actors involved. Further, will investigate soil and precipitation as factors of crop production. Investigations will help to create a compounded, grounded theoretical base which we shall use to investigate the food security, perception, and adoption rate of the technologies. Two econometric models will be developed, one will assess the effect of internal and external factors on farmers' decisions on practices whilst the other model will be for the prediction of the short- and long-term benefits (and costs) of the adoption of CSAT, putting into consideration the food security at the household level. A questionnaire survey will be used to collect data from selected districts of Southern and Western provinces. These areas are purposely selected because they fall in the agroecological zones I and II that have rainfall below 1000 mm and are areas most hit by droughts and floods, with agriculture still the mainstay for the locals. Two kinds of qualitative interviews and focus group discussions will be conducted focusing on the local stakeholders at the community level and stakeholders promoting CSAT at the regional and national levels. This study will ultimately help the national government and other stakeholders have a clear picture of the status core and enhance the development of strategies to reduce climate risk and vulnerability with the promotion of regional tailored use of green, sustainable technologies whilst addressing the devastating hunger and food security situation.

Keywords: Climate change, climate smart agricultural technologies

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How stakeholders perceive the ecosystem services and their well-being in the Corumbataí Geopark Project in Sao Paulo, Brazil

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Sustainable management involves caring on environmental, social and economic development, requiring effective policymaking. Worldviews, values and thoughts are some individual aspects that guide stakeholders´actions. Thus, understanding how decision-makers perceive their socio-ecological circumstances is key. The UNESCO Global Geopark Network promotes sustainable development of territories for geodiversity conservation privileging a bottom-up process. The Corumbataí basin, in São Paulo state, Brazil, holds important geosites, tropical forest patches, as well as the Guarani Aquifer System. The engagement of the COMTUR (Tourism Council) members is essential for the Corumbataí Geopark Project. Therefore this study invited COMTUR members (n=81) of the 9 cities that conform the Corumbataí basin to answer an online survey. The questionnaire consisted on a 1-4 Likert scale to evaluate how the stakeholders rely on ES to their wellbeing (WB). The Likert package from R software was used to assess the social-cultural valuation of WB and ES. We performed a Sankey diagram comparing WB and ES categories to comprehend the respondent's reliance on the ES for their WB using ggsankey package of R software. Among the WB categories, the majority highly valuated Health (59.3 %), Security (58.0 %) and Basic Material category as important (59.3 %). However, when it comes to relying on ES to their WB, we obtained a low correlation (less than 33 %) for all the compared categories, although Provision (ES) had the highest (16.67 %) number of significative linkages with Security and Health, WB indicators. Overall, there is a consensus about the appreciation of the categories of ES and WB, suggesting some agreement regarding their environmental and well wellbeing perception. Nonetheless, this assessment also suggests that most ES indicators are not perceived as correlated to their WB. Therefore, a framework aiming to engage the stakeholders on the Geopark Project based on an ecosystem services approach should target on highlighting the direct and indirect human wellbeing reliance on ES. Additionally, this study contributes to better understanding ecosystem services and human well-being perception in Latin America. Nonetheless, social and economic aspects can also influence social-ecological perception and further investigation is needed to comprehend them.

Keywords: Ecosystem services valuation, geopark, transition

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Assessing the significance of women in managing cattle business in eastern Indonesia: Implications for technology dissemination

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In the Indonesian culture, cattle business is usually considered as a male business. Yet, in reality, many women are actively involved in cattle business – from production to marketing and other decision-making activities. However, information on the role and significance of women in cattle business is limited. A survey was conducted in West Nusa Tenggara Province (NTB) eastern Indonesia to identify roles of women farmers in cattle production, farm business decision making, access to finance and to assess their self confidence to independently manage cattle business. Data were collected through a face-to-face interview of 500 respondents (250 men and 250 women) in 6 districts of NTB. The results show that almost 85 % of women are involved in collecting and providing feeds, and taking care of cattle. Women participates in decisions such as determining how much to spend for feeds (40.8 %); animal health (39.4 %); determining what cattle breed to raise (93.9 %) and which cattle to sell (36.6 %). Women respondents indicated that almost 56 % have access to capital from non-formal lenders and approximately 40 % from village cooperatives and none of them has access to bank loan as it has to be approved by their husbands. Women are confident to independently achieve cattle business objectives (57.3 %), to deal with difficult tasks (57.2 %), to be successful in cattle business (52.1 %), to overcome challenges (54.9 %) and to conduct multi-tasking (51.6 %). The results imply that there is very high active participation by women in cattle farming business in eastern Indonesia. They have significant role in cattle production, have access to finance and actively participate in farm decision making process and shown and build self-confidence to independently manage the cattle business successfully. Interventions and capacity-building programs targeting women is imperative to accelerate the uptake of technologies aimed at improving the performance of the cattle business.

Keywords: Cattle production, decision making, women participation

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Social innovations to heighten innovative resilience-building opportunities: the case of Madda-Walabu Woreda, Oromia

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Social innovation has re-emerged since the global financial crisis in 2008 as an approach to solving our collective intractable global challenges. Parallel with its renewed popularity, it is with paramount roles in the context of its application when planning to build environment or civic infrastructures or in resilience-building. The study area, Madda-Walabu, is one of the Woredas of Bale Zone, Oromia Region, Ethiopia. Agro-pastoralism is major economic activity of the Woreda. This research analysed results of social innovations to heighten innovative resilience-building opportunities in the study Woreda (thirteen Kebeles/villages). Focused on application of social innovations (integrated management (IM) toolbox and educational game (EG)) and results. These social innovations applied leaders/management of three small-scale irrigation Schemes, thirteen developed water supply schemes, and six micro and small entrepreneurs(MSE), and also cascaded to user groups at large. Stratified random sampling, and systematic random sampling methods applied select 391 user groups of the public infrastructures. Moreover, nine MSE members were selected using simple random sampling method. Descriptive statistics have been used. The result indicated that the social innovations are efficient and effective in building resilience within the communities through developing /enhancing transparency, accountability and management capacity of the management bodies of the small scale irrigation and water supply schemes. Moreover, the study realised that the social innovations developed performances of the targeted entrepreneurs. Prior to project intervention, major bottlenecks for poor services of small scale irrigation and water supply schemes include lack of transparency & accountability, lack of capacity & skills of the management bodies, traditional behaviours, access to spare parts, and technicians. The major barriers to successes of MSE include capital, market for their services & products, lack of business skills, fragile nature of MSEs, lack of proper human & material resources management and poor linkages with local government bodies. The intervention curbed the barriers and target groups resulted in efficient, effective and scalable achievements. The study recommends community based infrastructures and group-based businesses to use these Social Innovations in their operations to be efficient & effective, and attain built social, environmental and economic resilience.

Keywords: Businesses, educational game, IM toolbox, infrastructure, innovations, management, public, resilience, social

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Microbiome-based inputs: a technology to enhance agricultural productivity while replacing traditional synthetic inputs?

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Global food production relies heavily on the availability of synthetic fertilisers and pesticides, which can have well-known side effects on environmental and human health. Microbiome-based inputs, such as biofertilisers, biostimulants and biocontrol agents, have been gaining importance as promising alternatives to synthetic inputs, with estimated global market size of US$7.2 billion in 2019, according to a GVR report. This type of technology could reduce the quantities of chemical inputs used in agriculture while contributing to improved nutrient-use efficiency, plant resistance to abiotic stresses, and nutritional quality, thus contributing to some of the core principles of agroecology. Yet, the scientific evidence on the conditions under which microbiome-based inputs can fully deploy their potential is still inconclusive. The existing literature is scattered and disregards technological heterogeneities and the agroecological particularities of study sites. Against this background, this paper aims to synthesize findings from studies that quantify the effects of microbiome-based inputs on economic and environmental outcomes, such as yields and soil nutrient availability. We conduct a systematic review and meta-analysis, using the PRISMA protocol to structure the systematisation of literature and data. By using the package 'litsearchR', a novel semi-automated key term search approach, we expect a reduced selection bias in the literature review. We standardise the estimates, to compare effect sizes across studies, using Cohen's d. In addition, trial results and agricultural production systems are used as control variables to analyse under what agricultural conditions microbiome-based inputs are more effective. The outcomes will be presented by the type of microorganism used to develop the microbiome-based inputs, i.e. bacteria, root-associated fungi, and mycorrhizas. The findings of this paper will shed light on the role that microbiome-based solutions can play to boost productivity in agriculture while reducing environmental impact. Additionally, the paper can hint at knowledge gaps and possible research questions that help shape agroecological systems.

Keywords: Bio-based solution, input substitution, plant soil microbiome

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Water use with cloud computing: prospective for food and water security in smallholder irrigation schemes

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Growing water scarcity for agriculture calls for the adoption of prudent agricultural water management practices that can boost food production by producing more crops for each drop of water used. Understanding how irrigated lands use water over time is essential for planning and managing water allocation, water rights, and agricultural production. Our study aims to characterise and compare the spatiotemporal dynamics of agricultural water use. The study areas are two different rudimentary irrigation schemes in a west African semi-arid area (Burkina Faso) context. The lakes around each study area, which are the main water resource for irrigation, are shrinking. This is due to both competition amongst users and climate change. Open remote sensing data on the cloud-based platform Google Earth Engine with its large Landsat dataset over the last 35 years have been used for the analysis. The indicator 'water used per surface' is derived via actual evapotranspiration from a surface energy balance model. A per pixel trend analysis shows changing water use at field level. The research demonstrates the utility and advantages of using cloud computing. It offers, automated workflow that enables relevant, more rapid, and cost-effective updated information for water management in data scarce and informal environment. Up-to-date and basin-wide evapotranspiration information is a crucial input in hydrological models capable of simulating the future impact of water management decisions made today. The results also discuss the implication for the future generations on securing food production without having to increase croplands and/or greater water use. Subsequent studies should investigate the understanding of crop water productivity to improve food security and better water management strategies with the increasingly limited water resources.

Keywords: Evapotranspiration, google earth engine, thermal remote sensing, time series, water use efficiency, West Africa

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Recycling resources from coffee by-products via hydrothermal conversion for sustainable coffee farming in Vietnam

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Vietnam is the world's second-largest coffee-producing country, depending on over half a million smallholder households, most with less than 2 hectares, to produce 95 % of its coffee production. However, Vietnam's coffee sector is facing challenges to remain competitive: 1) world market pressure to improve product quality, 2) climate change with threats of drought, pest, and disease attack, 3) the need to promote product diversification. Measures to meet these challenges range from expanding the wet-processing capacity of coffee berries, to improving the resilience of the growers through agroecological farming and ensuring that sustainable production standards are met throughout the value chain. While wet-processing can make farmers and the whole value chain less dependent on weather conditions and produce higher quality coffee beans, new challenges arise from the centralised production of large amounts of by-products in these plants. Approaches and technical methods to support local recycling of the nutrient and carbon resources in the coffee by-products are required in keeping with the agroecological farming principles. The conversion of the coffee by-products to stabilised carbon-rich materials that can be returned to the coffee farmers as a soil improver and fertiliser is the focus of this study. The hydrothermal carbonisation process (HTC) was used to enhance the properties of coffee by-products for carbon and nutrient recovery. In the HTC process, the by-products are thermally converted to a solid, hydrochar, and a liquid, the process water. Experiments with various waste streams from a coffee processing plant in Vietnam were conducted to determine the influence of HTC conditions on the recovery efficiency for carbon and nutrients in the products. The goal was to optimise the HTC process settings and post-processing steps to yield products that can be used as soil improvers for coffee plantations. The product composition was characterised and the values were compared to European and international standards for soil additives. The overall recovery efficiency for carbon and nutrients caused by the process steps was evaluated. The technical feasibility of the proposed process combination with HTC will be discussed based on its potential costs and benefits for the coffee value chain.

Keywords: Carbon and nutrient recovery, coffee farming, coffee value chain, hydrothermal carbonisation, sustainability

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Towards early responds to desert locust swarming in eastern Africa

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On top of food security constraints by the Corona pandemic and climate stressors, desert locusts (*Schistocerca gregaria*) pose an additional livelihoods threat to communities in eastern Africa. The Food and Agricultural Organisation (FAO) of the UN has developed desert locust modelling routines that are able to identify most suitable regions for swarm attacks and movement of bands (and thus can help to scale out interventions). However, controlling these insects at this stage of their life cycle (adult) is extremely difficult, hence a comprehensive early warning alert system is needed to facilitate early response at a juvenile stage. In this regard, the German Aerospace Center (DLR) in cooperation with the International Centre of Insect Physiology and Ecology (icipe) (Kenya), have teamed up to develop a geospatial monitoring routine that can predict timing of locust hatching in eastern Africa. The monitoring routine is based on spatially explicit geospatial data, particularly from satellite observations, while locally assembled field survey data on hatching of bands (from Sudan and Kenya) are used as reference data. Specifically, a fuzzy logic model was implemented that uses data ranges from newly available climate data (temperature and rainfall at 25 km grid cell resolution from the NASA Power platform; https://power.larc.nasa.gov/) and processed satellite observations (on vegetation density). All data sets were processed for the same historical period (2016 to current). The model was initially developed (trained) for a region in Red Sea state in Sudan. Subsequently, the model was validated and applied to northern Kenya. Given the time range between hatching and formation of hopper bands, we estimated the timing of hatching for several periods within the rainy seasons (October to March), for both countries, respectively. A spatially explicit model output showing hatching probability was produced for Kenya, showing hatching "hot spot" areas, and associated timing of hatching, in Turkana and Marsabit counties, respectively. This is a first step in operationalizing an early response to locust infestations at juvenile stage of the pest development for control strategies to be easily applied.

Keywords: Africa, desert locust, early warning, earth observation, food security, modelling

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Water consumption and wastewater produced in tofu industry: Evidence from Indonesia

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In the small, medium, and large-scale tofu industry, large amounts of water are consumed during the processing, which produces large quantities of wastewater and negatively affects the environment. Even though, there is existing legislation in the form of the Regulation of the Governor of Lampung Province 2006 stating the quality standard of tofu waste water is pH 6–9, TSS 60 mg L^{-1}, BOD5 75 mg L^{-1}, COD 200 mg L^{-1}; the common practice is that tofu wastewater is directly disposed of without any pre-treatment first. This practice causes odor and pollutes water bodies around the industry to settlements far from industrial areas. The process of making tofu consists of soaking, soybean grinding, boiling, filtering, acidification, molding, and packaging, of the whole process, only molding and packing do not need the water. This study aims to determine how much water is consumed during processing production and the wastewater generated in the tofu industry. The data collection was conducted via semi-structured interviews and questionnaire surveys with 40 owners of small and medium-scale tofu industries in Gunung Sulah District, Bandar Lampung City, Lampung Province, Indonesia, in December 2020. The data were analysed using a mass balance to determine how much wastewater was generated. The results show that the water consumption for processing production in the tofu industry is 25.18 L kg^{-1} of soybean, and the wastewater produced is 14.59 L kg^{-1}. Hence, approximately 54.31 % of wastewater is generated from the water consumed. Furthermore, tofu wastewater has a high potential to be used as a feedstock for biogas generation because it has a high organic content such as COD 12,400 mg L^{-1}, TS 3800 mg L^{-1}, TSS 1188.25 mg L^{-1}, alkalinity 280 mg L^{-1}, VFA 1500 mg L^{-1} and pH 5.17. This study provides a preliminary result for the subsequent study to use tofu wastewater as a biogas feedstock to make the tofu industry a green circular industry with more environmentally friendly and sustainable features.

Keywords: Biogas, tofu industry, wastewater, water consumption

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Analysis of determinants of adoption of service-based business of digital agricultural extension technologies: an *ex-ante* evidence

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Agricultural extension plays a crucial role in agriculture development, and its efficiency is still a real challenge that needs attention, especially to achieve the 2030 Sustainable Development Goals. The rise of digital agricultural extension technologies is an opportunity to support and improve the traditional extension approach. However, even if farmers are willing to use digital farming technologies, barriers such as access to information technology (IT) devices (smartphone, internet, electricity, etc.), low e-literacy, and poor knowledge of IT tools make adoption difficult. This study aims to overcome these barriers through a service-based business approach. This study proposed ten theoretical business profiles (based on RiceAdvice technology services) to farmers and used the choice experiment to analyse the determining factors of the preferred business profiles. We also identify the most preferred business profile, essential attributes, and socio-economic factors for an optimum business profile. Results showed that gender, age, education level, knowledge of the technology, and household income are the determinants of the preferred business profile. Among the ten business profiles, business profile 3 is the first most preferred with 49.4 % implying cash payment after harvest at 9.70 USD ha^{-1} for more than two seasons contract, followed by business profile 6 with 44.7 % with cash payment after harvest at 14.5 USD ha^{-1} for one season contract and the business profile 1 with 26.8 % implying cash payment at 14.50 USD ha^{-1} for a one-season contract. The optimum business profile would include all education levels, with 14.50 USD ha^{-1} as the optimum price for a cash payment after harvest with no access to credit. This study provides a framework for sustainable dissemination of digital farming technologies and an operational template for a service-based business using digital farming technologies to promote private extension firms taking advantage of the new agricultural technologies.

Keywords: Agricultural extension, business profile, extension application

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Food for all, water for all, agriculture takes it all: Water management in African agriculture

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The world population is growing, and the nutritional requirements of this growing population must be met. The SDG 2 seeks sustainable solutions to end hunger by 2030. Whereas SGD 6 establishes global water management efficiency and water quality objectives. Sadly, while agricultural intensity is increasing to feed the world, it comes with substantial environmental collateral damage such as excessive groundwater withdrawal, greenhouse gas emissions, and pollution of water bodies. The role of agriculture as a villain and victim cannot be neglected. Agriculture is responsible for more than 70 % of global water consumption. Similarly, it is the third major source of water pollution. Therefore, the achievement of these SDGs is strongly influenced by the way water is managed in agriculture. Thus, this study emphasises the impacts of several agricultural activities on water resources, specifically the quantity and quality of water. Agricultural activities with a high-level water footprint and greenhouse gas emissions are also highlighted. Although developed countries have intensified research and development in battling these crises, developing countries, especially in Africa, are still laggards. Therefore, a commentary is presented on the life cycle assessment of agricultural activities in Africa. Similarly, to offset the underlying environmental impacts of these water-related processes, which cannot be eradicated, expansion of the wastewater treatment value chain is proposed. The recoverable resources along the wastewater and sludge lines are enumerated, as well as their potential market values. However, stakeholders must be involved in creating robust models to promote and implement recovery practices. In addition, there is a need to intensify research to deal with the economic, environmental, social, and technical aspects of the wastewater treatment value chain valorisation. Thus, initiating a paradigm for the conversion of wastewater treatment facilities into water resources recovery facilities. Other motivations in addition to mitigation of environmental impacts include additional revenue generation and cost reduction from a life-cycle perspective.

Keywords: Africa, life cycle assessment, SDGs, waste valorisation, wastewater treatment, water resource recovery, water reuse

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Adoption of conservation farming practices for sustainable rice production among small-scale rice farmers in Barotse floodplains in western Zambia

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Conservation farming practices (CFP) provide various economic, social, and cultural benefits to the welfare of small-scale farmers and contribute to the sustainable rice supplies for 3.5 billion people that depend on this crop at a global level. Additionally, the use of CFP also contributes to combating climate change. Rice represents a traditional crop for many African countries, including Zambia, where one of the most important production areas is the Barotse floodplains at the upper watershed of the Zambezi river. Local farmers plant traditional and improved rice varieties, taking advantage of their particular characteristics. Nevertheless, population pressure, structural changes and commercialisation tendencies endanger the sustainability of local rice farming systems. The most important aspect for the farmers is to have a positive attitude toward the environment in their daily farming practices to produce good quality and environmentally friendly rice. Thus, the study aims to provide an overview of policy papers and current development efforts in western Zambia towards sustainable rice production and document which local rice varieties farmers prefer and what conservation techniques are applied for particular rice varieties. Moreover, the main drivers and barriers to the adoption of sustainable practices will be identified as well. Data for the first aim were collected through the relevant internet sources and government institutions, and data on profitability, perceptions and sustainable practices through key-persons interviews, focus group discussions, and household surveys among rice farmers in six districts of Barotse floodplains. Results show that farmers are using a wide range of rice varieties, traditional and improved, to deal with weather conditions, meet food security and reach the market. Nevertheless, despite the promotion of conservation and sustainable practices, the adoption rate remains rather low.

Keywords: Adoption barriers, climate change, cooperatives, profitability, rice varieties

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Rapid appraisal of innovation support services in agricultural innovation systems for agroecological transition: the Raissa approach

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The agroecological transition (AET) has never been so crucial than our current dispensation. First, we witnessed COVID-19 and just when one thought, we were out of the woods, the Russia -Ukarian war has further deepened and complicated the woes. The disruptions to supply chain for agricultural inputs, specifically fertiliser is worrying. Indeed, producers using very few inputs or locally produced organic inputs were less affected in their production practices than those heavily dependent on synthetic agricultural inputs. Developing countries were particularly affected due to the scarcity of these inputs and the cyclical increase in their prices as a result of the slowdown in international trade. There is therefore an interest in strengthening the support to the actors (farmers,farmer based organisations, processors, advisors, policy makers....) engaged into AET. This transition anticipates that agroecological innovations (AE) are developed at niche level to enable the breakthrough of the novelties in the regime when windows of opportunity are opened by the landscape. For that to happen, agro-ecological innovation niches should be supported. The Rapid Appraisal of Innovation Support Services in Agricultural Innovation Systems for Agro-ecological Transition (RAISSA) aims to produce an innovative approach and tool for performing diagnoses of support service ecosystems that constitute subsystems of the agricultural innovation system (AIS). The RAISSA approach will complete the range of existing AIS diagnostic tools by identifying and prioritising existing and missing innovation support services (ISS) dedicated to supporting AE. This rapid diagnosis mobilises the Q methodology which is a powerful and statistically rigorous tool. The aim of this paper is to present the RAISSA approach and its interest for decision makers to formulate and orient innovation policies toward AET. The approach has been applied to the Ghanaian context where

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the AIS concept is being increasingly mobilised for political decision support. The results show that having an insight into the range of perceptions about the ISS within the actors evolving in a given system, and how these perceptions differ or converge contributes to the formulation of recommendations to decision-makers on the services to deploy or implement relevant policies.

Keywords: Agricultural innovation system, agroecological innovation, Ghana, innovation support service

Willing to adopt precision agriculture technologies by farmers in Ghana

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Agriculture in developing nations like Ghana faces many challenges, and experts advocate various management strategies based on existing and proven technologies to improve agriculture. Reduced productivity per unit area, dwindling and degrading natural resources, the growing threat of global warming and climate change, and stagnant farm revenue are major obstacles to agricultural success. Hence, meeting future challenges in an ever-changing world will require novel technology-based responses may be required. Precision farming is a concept that combines a variety of technologies such as GPS technology, variable rate remote sensing, yield mapping, and other tools to improve profitability, sustainability, and environmental impact for site-specific crop management. As a result, the focus of the study was on farmers in Ghana. The study looked at the Factors influencing awareness and willingness to adopt precision agriculture technology, namely variable rate remote sensing and yield mapping in Ghana. A cross-sectional survey was conducted among 122 farmers selected using multi-stage sampling in Ghana's two farming regions, Bono East and Bono, from March to May 2022. Descriptive analysis and binary logistic regression were used to determine the factors influencing the willingness to adopt precision agriculture technology in Ghana. The descriptive analyses show that farmers in Bono (63 %) were willing to adopt precision agriculture as against the Bono East region (37 %), (85 %) of male farmers were willing to adopt than female farmers (15 %). The regression results show that years in farming, landownership type, and source of funds positively affect willingness to adopt precision agriculture technology ($p < 0.001$, $p < 0.01$, $p < 0.1$, respectively), and age negatively affect willingness to adopt precision agriculture technology ($p < 0.1$). Based on our findings, the study recommended, among others, the need to create awareness among farmers and other major stakeholders of the potential benefits of precision agriculture technologies in Ghana.

Keywords: Adoption, precision agriculture, technology, willingness

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Factors influencing the adoption of sustainable livelihoods: a case study of smallholder cocoa farmers in the eastern region of Ghana

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Cocoa remains one of the leading cash crops in Ghana and most countries in sub-Saharan Africa. Regardless of its numerous benefits, cocoa is sometimes subject to changes in climatic conditions such that limited or excess rainfall and temperature can reduce the quantity produced at the end of a season. This means that cocoa farmers should have an additional livelihood to sustain them amid unpredicted and unexpected weather events. The German Government, Ministry of Food and Agriculture and Ghana Cocoa Board, have collectively trained cocoa farmers in the Asamankese cocoa district on sustainable livelihood programs (SLP) to help them increase their livelihood and generate more income. However, the adoption of SLP is low within the Asamankese cocoa district. The study's main objective is to explore the factors that influence farmers' adoption of sustainable livelihoods.

300 cocoa farmers from the project were sampled randomly from the district and interviewed using structured questionnaire. Binary Logistic regression was used to establish a relationship between SLP adoption and factors that influence it. Cronbach alpha ($= 0.81$) was used to test the reliability of most of the Likert scale questions. Findings revealed a significant relationship between the socio-cultural background, economic, environmental, and personal factors and SLP adoption. It was also revealed that farmers fully engaged in other livelihood programs tend to increase their income, livelihood, crop yield, food security, and others. Such farmers can increase their cocoa production by generating income elsewhere to purchase inputs. They do not solely depend on cocoa for survival as yields decrease between years. The study recommends that the government of Ghana should ensure effective collaboration with most NGOs interested in the Sustainable Livelihood of farmers and work for hand in hand with them to support farmers. Also, inputs should be made available for farmers who want to venture into other sustainable agri-business programs.

Keywords: Adoption, smallholder cocoa farmers, sustainable livelihood programs

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Comparative study of biogas production from anaerobic bio-digestion of peelings and effluents from cassava processing factories in southern Benin

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In Benin, the growth of cassava processing agro-industries generates significant quantities of waste: cassava peelings and effluents. Although these wastes are bulky and harmful to health and the environment, they can be recycled into biogas. This study aimed to compare biogas production from anaerobic bio-digestion of peelings and effluents, two by-products of cassava processing into gari in southern Benin. The experimental device was a Ficher block comprising the following seven treatments all added to 400 g of water: 1st treatment (T1) consisting of 400 g of crushed cassava peelings; T2 composed of 300 g of peelings and 100 g of cow dung; T3 composed of 200 g of peelings and 200 g of cow dung; T4 composed of 400 g of effluent; T5 composed of 300 g of effluent and 100 g of cow dung; T6 composed of 200 g of effluent and 200 g of cow dung; T0 (or control) composed of 400 g of cow dung. The results showed that the average volumes of biogas for the treatments T0, T1, T2, T3, T4, T5 and T6 were respectively around 40.74 ml on the 25th day, 11.74 ml on the 33rd day, 13.48 ml on day 31, 22.61 ml on day 29, 24.35 ml on day 27, 23.04 ml on day 27 and 34.13 ml on day 21. The variance homogeneity test (p=1,15.E-05) carried out revealed a significant difference between the average volumes of biogas. However, multiple comparison tests revealed that T6 provides better performance in terms of biogas than T0. Finally, the biodigestion of cassava effluents can be considered as system to improve the production of biogas using the wastes from cassava processing in southern Benin.

Keywords: Benin, bio-digestion, biogas, cassava peelings, cow dung, digester, effluents

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Effects of credit on the adoption of drudgery-reducing crop production techniques in northern Ghana

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Agriculture continues to play an important role in the lives and livelihoods of smallholder farmers in developing countries. However, the role agriculture plays in improving the nutritional status of farmers is still being questioned, particularly because of a lack of strong correlation between agricultural productivity increase and nutritional outcomes observed in many developing countries. Some authors attribute the weak relationship between agricultural production increase and improved nutritional statuses of farmers in developing countries to the high level of drudgery and human labour expenditure that characterise crop production among smallholder farmers. Indeed, there is evidence of negative energy balance observed among West African farmers because of higher calorie expenditure relative to consumption, particularly during the growing season. Recent literature shows a negative association between agricultural cropping work and nutritional status, as measured by body mass index (BMI) for non-overweight individuals in developing countries. Thus, drudgery reduction in the cultivation of crops by smallholder farmers in developing countries has been identified as a potential pathway through which agriculture can improve the nutritional status of non-overweight farmworkers. One drudgery-reducing strategy is to substitute manual land preparation and manual weed control for tractor ploughing and herbicide weed control respectively. However, adopting these drudgery-reducing cropping strategies come with financial costs, which is a constraint to smallholder farmers. Hence the objective of this research is to examine how credit-constrained farmers will adjust their cropping plans to reduce total labour energy expenditure when they are provided with a credit facility. The role of farmers' access to credit in the adoption of improved agricultural technologies is well documented in the literature and this research intends to contribute to that. Using preemptive goal programming, we construct a household model for a typical farm household in northern Ghana to analyse the effects of credit provision on the adoption of drudgery-reducing cropping techniques. Our analysis shows that the provision of credit at a 25 % interest rate per annum to credit-constrained farm households in northern Ghana enables them to adopt drudgery-reducing production techniques. We also observe a trade-off between total energy expended in crop production and amount of credit households can borrow.

Keywords: Credit, mathematical programming, nutrition, smallholder farmers

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Opportunities and challenges for an innovative solar milk cooling system in Zambia: a case study

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The low electrification rate in rural regions, the low milk production volumes of smallholder farmers and the changing consumption habits for milk and dairy products suggest potential for small to medium scale solar milk cooling systems in Zambia. The University of Hohenheim and Solar Cooling Engineering UG (Köngen, Germany) have developed a modular solar cooling system. The technology is based on the use of vapor-compression refrigeration units to produce ice, which is then used as a cooling medium. The modular approach enables an adaption of the system to the operators' needs in terms of capacity and design. This case study examines the economic feasibility of the proposed system for different sizes, as well as characteristics of potential users in terms of milk production and marketing in the Zambian southern province specifically the Zimba region. The economic feasibility was determined for systems with a cooling capacity ranging between 80 and 500 L of milk per day by the calculation of the net present value (NPV) and internal rate of return (IRR). The costs of the potential systems were estimated based on the local assembly in Zambia and were compared to an on-grid solution. Essential data was obtained by conducting interviews with experts in different key positions and a survey among off-grid smallholder farmers without affiliation to dairy cooperatives (mixed methods). The economic feasibility of the systems highly depends on the location and accessibility for off-takers, financing method, margin of the operator as well as the extent of utilisation during dry season, favouring scenarios where no transport of milk from the operators' side is required. While higher volumes increase the likeliness of milk pick-up by processors, the prices of the higher volumes systems are posing a major challenge. Moreover, a successful implementation is influenced by different contextual production characteristics, like the range of farmers' individual milking times, as well as milking periods, calving intervals and months in dry season which are intensifying a drop in milk production volumes. This study is an example of the importance of field study before introduction of technological innovations.

Keywords: Dairy smallholder farmers, economic feasibility study

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The link between agroecology and adoption of soil erosion control in local discourses

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Agroecological approaches have been recommended for providing context-specific solutions since they consort the socioeconomic and ecological constraints among farming communities. This study is the first attempt to conceptualise agroecology in the context of the challenge with the adoption of soil erosion control measures. Through a qualitative design (using interviews and focus group discussions), we explore a case of smallholder farmers producing *Coffea arabica* on the Rwenzori mountain highlands in Uganda. Here, adoption of soil erosion control measures remains a challenge despite the increasing efforts through conventional agricultural advisory services. We contrast the elements of agroecology with the discourses among the actor to identify if it would provide a panacea for sustainable adoption of soil erosion control measures. Our results indicate that sustainable soil erosion control can be hitched on the agroecology elements broadly categorised under; (1) participatory development of appropriate (efficient, diverse and recyclable) soil erosion control measures, (2) clear roles for the different actors to concurrently implement soil erosion control processes (synergies, resilience and respect for culture and food traditions) (3) Strategies for enabling sustainable adoption of soil erosion control measures (co-creation and sharing of knowledge, human and social values, responsible governance, circular and solidarity economy). Despite farmers, cultural, religious and farmer institutions hitching the sustainability of soil erosion control on an agroecological approach, government extension advisers are locked-in a top-bottom approach that results into short lived adoption. We recommend that (1) agroecology elements be seriously considered in designing soil erosion control initiatives (2) government extension advisors be trained on agroecology to appropriately respond to context specific constraints to sustainable adoption (3) cultural and religious leaders should implement a reward and punitive system for adopters and non-adopters respectively.

Keywords: Agroecological elements, *Coffea arabica*, discourse analysis

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Impact assessment of waste-to-resources management for circular economy development and green growth in Nigeria and Ghana

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Poor waste management results in environmental and socioeconomic problems in Nigeria and Ghana. Attempts at managing waste through burning can lead to climate change while landfill leachate reduces soil and ground water quality. Hence, the need to look for better alternative. This research looks at the current challenges in the waste management system in Nigeria and Ghana, as well as proposes a more contemporary system that will move the two Anglophone countries towards attaining a circular economy.

Environmental Kuznets Curve hypothesis provided theoretical framework. Purposive sampling of major landfills in Nigeria and Ghana with their waste generation pattern using structured questionnaires(250) on spatial-variation, challenges and prospect of waste management practices were done. The results were validated at expert workshop for key officials within the waste management industry. Data were analysed using descriptive and inferential statistics. Waste habits of Nigerians were 57 % organic, 27 % plastics, 5 % glass, 5 % metal and 4 % others, ending up mostly on landfills/dumpsites. Only 28.1 % & 41.8 % separated waste at source, 46.2% & 58.5 % used private collection services in Nigeria and Ghana respectively. The major waste management challenges were pollution and health risks (69.1 %), limited resources (44.8 %), lack of technical skill (23.8 %) and inadequate management skill (18.1 %). As part of waste management practices, 95.2 % & 97.6 % were willing to participate in circular economy, 94.3 % & 98.1 % supported polluter-pays-principle, 96.2 % & 98.5 % supported dissemination of public information on Waste-to-Resources in Nigeria and Ghana respectively. Waste management challenges significantly influenced health issues and pollution in both countries ($p = 0.05$).

A theory-of-change was established to capture the activity, outputs, results, outcomes, impact and the sustainable-development-goals (SDGs) realised. With the implementation of waste-to-resources projects in Nigeria and Ghana, some of the outputs are; production of clean-energy, improved sanitary conditions of markets and slaughter-houses, production of compost-fertiliser for urban agriculture, and cultivation of green vegetables. Both Countries are

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now benefiting from the operations and services of the Pioneers, customers also patronize, buy and recycle products. The impact cut across clean-environment, health, food-security, increased-income and 8 SDGs-realisation. Government has a role in creating an enabling environment and stimulating demand to sustainably transits from current linear to circular economy in the West African Countries.

Keywords: Challenges of waste management, circular economy, green environment, theory of change, waste-to-resources

Agricultural livelihoods between development and disruptions

Effect of corruption on farmers' participation in agricultural production support programmes – evidence from Ghana

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Literature show that agricultural production support programmes can enhance farmer adoption of better technology and inputs, increase productivity, and subsequently enhance food security. However, corruption, such as preferential treatment to political allies of governing parties, input smuggling and elite capture, often demotivate vulnerable smallholders in sub-Saharan Africa (SSA) from participating in such interventions although they are the primary target of such interventions. Seminal studies and reports show that corruption (actual or perceived) has a significant economic effect on the success or otherwise of agricultural policies and programmes. Yet, empirical findings on the effect of corruption on farmers' participation in agricultural support programmes are rare. This study therefore evaluates the effect of corruption perception (i.e., perceived input smuggling, elite capture, and political favouritism), positive attitude (i.e., perceived programme benefits – increased productivity and income) and other factors on farmers' decision to participate in production support programmes using Ghana's Planting for Food and Jobs (PFJ) programme as a case. Data for the study was collected through quantitative survey in Northern Ghana with 540 respondents from December 2018 to April 2019. Findings from our logistic regression model show that farmers are more likely to participate in the PFJ programme if they perceived high benefits – increased productivity, and income (i.e., positive attitude towards the programme). On the other hand, corruption perception about the PFJ programme decreases farmers' probability to participate in the support programme. Furthermore, high level of corruption perception decreases, at higher value, farmers' positive attitudes toward the programme which reduces their probability to participate in the PFJ programme. Positive attitudes should be complemented by low level of corruption perception about production support programmes to increase farmer participation.

Keywords: Attitude, corruption perception, Ghana, planting for food and jobs programme, production support, risk awareness

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Farm typology and farming households livelihood: a case study of Osun State, Nigeria

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Agriculture remains the primary source of livelihood for the majority of households in developing countries. However, there exists a diversity of farming systems among farming households, arising from variation in household characteristics and resource endowments. This heterogeneity in farming systems interplays with the livelihood of these households. Therefore, understanding the farming systems practised by different farming households can provide a valuable framework for designing development policies and interventions. Hence, the study examined the relationship between the farm typologies and the livelihood of farming households in Osun State, Nigeria. The present study used the data collected from 120 farming households selected through a three-stage sampling procedure to create 3 farm types using the principal component analysis and cluster analysis. Descriptive statistics was used to describe the characteristics of the households selected for the study. The study also adopted the sustainable rural livelihood index to determine the livelihood status of the farming households and the Pearson's correlation analysis to determine the relationship between the identified farm types and the livelihood of the farming households. Findings from the study revealed that the majority of the households are smallholders with less than 2 hectares of farmland holding. The cluster analysis result revealed that majority (66.7 %) of the farming households practise a rainfed farming system characterised by crop-livestock subsystems with major production of food crops and poultry, 22.5 % of the households practise an irrigated farming system dominated by crop production with major production of food crops, and 7.5 % of the households practise a rainfed farming system characterised by crop-livestock subsystems, with major production of perennial crops (cash crops) and small ruminants. While the livelihood analysis also revealed that majority (68.3 %) of the farming households have average livelihood status, the correlation analysis result revealed that the variables determining farm types including age, total land holding, portion of land cultivated, herd size, area of land under irrigation, commercialisation index, and income source are positively associated with the livelihood status of the farming households. Hence, the study provided a basis for designing multilevel interventions aimed at improving the livelihood of smallholder farming households in the study area.

Keywords: Cluster analysis, farm typologies, farming households, livelihood, principal component analysis

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Accounting for heterogeneities in the adoption of organic farming: Evidence from Benin

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Not all farmers are expected to be early adopters of innovations, especially those of a radical type. In order to understand the potential adopters' profiles, organic standards promoters should try to work with attributes affecting the decision to adopt organic farming early, lately, or not to adopt it. In this regards, we analyse the factors behind the adoption of organic farming by accounting for heterogeneities in the adoption stages. We conduct the study in two major cotton-growing areas in Northern Benin. A sample of conventional and organic cotton farmers was surveyed randomly in 14 representative villages. We collect cross-sectional data about farmers' characteristics, motives for conversion, perception, and attitudes. We use both qualitative and quantitative analyses and show that the factors driving the adoption of organic cotton differ across adoption stages. We demonstrate that social identity influences cotton production and guides the choice of the production methods. Receiving price premium, preserving farmer's health, avoiding pesticides handing and obtaining better farm profit are the most important motives. While most early adopters care more about their health, as they are older and more vulnerable to disease, late adopters are guided by price premium. Profit orientation and environmental awareness are the main drivers for all groups of adopters, and adopters are less information seeking-oriented than non-adopters. Early adopters have a smaller farm and higher livestock units than late adopters, and they are actively in contact with advisory services. Consequently, policymakers promoting innovation can take into account those attributes when targeting farmers at different adoption stages as a way to increase the adoption rate.

Keywords: Dietary diversity, farm households, food security, organic farming, treatment effects

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Institutional innovation for improving food security based on agroecological integrated farming in developing countries: Evidence from Indonesia

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Food insecurity is main challenge, not only in Indonesia, but also in the rest of the developing world, and has become more serious in the midst of the COVID-19 pandemic and impacts of the climate change-induced risks. The recent Global Food Security Index (2022) indicated that Indonesia's food security decreased in 2021 from the previous year. There are concerns that the lack of appropriate government policies are some of the main contributing factors to decline of food security performance. It is believed that institutional innovations at the grass root and local levels are strategies to improve food security. The purpose of this paper is to evaluate the deliverable outcomes of the collaborative research between the Livestock Development and Research Center, Ministry of Agriculture, and University of Mataram (Indonesia) in collaboration with the University of New England (Australia) which is supported by the Australian Centre for International Agricultural Research (ACIAR) on changing of local government organisations in increasing livestock production based on integrated agriculture (aka Crop-Cow). The perceptions of farmers and key stakeholders, along with other qualitative indicators, were collected using in-depth key informant interviews and focus group discussions in six districts in the province of West Nusa Tenggara, Indonesia. Research findings showed that the institutional innovations implemented by collaborative work have encouraged increasing capacity and changing the ways of working of government staff in establishing work plans and local policies to increase food production of Crop-Cow integrated farming in line with national food security policies. Our results highlight the need to develop and implement an institutional innovation focused on local government organisations to advocate policy changes for improving food security governance based on local agroecological conditions focused on poor farmers in order to ensure that 'no one is left behind' in the quest towards 'zero to hunger'.

Keywords: Agroecological, food security, innovation, institution

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Exploring the wellbeing of communities adjacent to coastal forests: a case study from Sri Lanka

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The well-being of communities living adjacent to coastal forests plays an important role in their conservation and management. The positive outlook of communities towards these forests helps to plan sustainable conservation trajectories. This study outlines different dimensions of the well-being of coastal communities living closer to Mandaitivu on the Northern coasts of Sri Lanka. A well-being questionnaire survey was carried out among 30 households from July to September 2021. The well-being approach conducted focused on the human, social, and material concerns and how these three are related to coastal forest services, disservices, ecosystem processes and functions. The results for human concerns showed that 90 % of the respondents relate that the mangrove ecosystem contributes to their happiness while 100 % think that mangroves are not dangerous. About 80 % do not fear the coastal forest ecosystems and encourage conservation. Considering the social concerns none of the respondents think that forest ecosystems help them in enhancing their relationships with others and 90 % of respondents believe these ecosystems are culturally important. Even though coastal ecosystems were destroyed by the 30-year civil war which ended up in 2009 none of the respondents believes that these ecosystems remind them of violence, conflict, and insecurity. Only 20 % of the respondents have a clear understanding of mangrove-related laws, regulations, and local bylaws and are satisfied with the current legal enforcement related to coastal forests. When considering the material concerns only about 20 % of the respondents are getting environmental resources goods and services. Around 50 % of the respondents think that the coastal forest spread/enhancement makes them happier now than before. Coastal communities are marginalised in the decision-making processes related to coastal management in Sri Lanka. In order to develop sustainable cost conservation initiatives, we recommend the consideration of the well-being of coastal communities so that they can act as guardians for sustainable coastal forest management in Sri Lanka and beyond.

Keywords: Co-management, environmental governance, participatory approach, social-ecological systems

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Trends and prospects of wheat self-sufficiency in Egypt

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Egypt is the most populated country in the Arab World and the third most populated in Africa. For centuries, wheat has been central to Egypt as the most important food crop and diet. Today Egyptians derive one-third of their daily caloric intake and 45 % of their protein intake from wheat-based food, mainly in the form of subsidised bread called baladi. Wheat is mainly produced along the River Nile and in the Nile delta by millions of smallholders. However, Egypt is the world's largest wheat-importing nation, with only less than half of the national consumption being met by domestic production. 80 % of wheat imports in Egypt come from Russia and Ukraine. Upon this backdrop, gaining wheat self-sufficiency is an overall aim of the Egyptian government. This study provides an overview of the degree and trends of wheat self-sufficiency in Egypt between 2000–2019, followed by an analysis of the concerning external pressures and system-immanent drivers to achieve wheat self-sufficiency in a sustainable way. Empirical data were collected in the River Nile delta in the 2020/2021 growing season. Interviews were collected with 246 smallholder wheat producers in four divisions in Beheira Governorate. Additionally expert interviews and focus group discussions with smallholders, agriculture cooperative representatives and extension agents were conducted. The analysis stresses some of the weaknesses of the wheat production system in Egypt that should be addressed to make production more efficient. The study underlines some critical external pressures and system-immanent drivers influencing wheat cultivated area and productivity. Wheat producing smallholders need to have more active participation in decision making to contribute to more food security in Egypt.

Keywords: Egypt, food security, self-sufficiency, sustainable agriculture, wheat

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Voluntary sustainability standards and social sustainability outcomes among Ethiopia's smallholder coffee farmers: a systematic review

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Voluntary sustainability standards (VSS) have been widely used as a tool to improve the living standard of smallholder farmers and create alternative options to protect smallholder farmers from a periodic crisis. Several studies have analysed whether sustainability standards–such as Fairtrade or Organic–deliver on their promise to benefit smallholder farmers in developing countries. The results obtained are mixed. Reasonably, the larger share of these studies had given higher attention to the economic and environmental aspects of sustainability. Nevertheless, the social sustainability component is less explored. In this study, we synthesize the contributions of previous studies (in terms of methodologies, research gaps, and key findings) focusing on Ethiopian smallholder coffee farmers. Thus, the broader review objective is to summarize previous research works on the topic of "Voluntary sustainability standards and social sustainability outcomes among Ethiopia's smallholder coffee farmers". We conducted a systematic review to consolidate results from original published articles. The systematic review study used a wide range of sources and followed a systematic literature review step-by-step PRISMA procedure. The finding analysed the aspects of sustainability. Accordingly, compared with other components of sustainability outcomes the systematic review showed limited evidence on the social sustainability outcome brought about by compliance with VSS. Our finding also confirms most of the reviewed articles given less attention on social aspect of sustainability. Our review result found out awareness among households plays a vital role in affecting compliance to the social sustainability component. Cooperative performance, Coffee production systems, high production costs, access to credit and weak price transmission play major role in affecting stallholders' compliance to VSS.

Keywords: Coffee, Ethiopia, systematic review, voluntary sustainability standards

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Measuring women's empowerment in Kenya and Zambia: a comparison of two studies using the pro-WEAI index

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Women empowerment is considered a critical pathway of increasing women's ability to make strategic decisions regarding agriculture and their access to the physical and social capital required to implement these decisions. The poster is based on two studies implementing an adapted versions of the Project-level Women Empowerment in Agriculture Index (pro-WEAI). The pro-WEAI instrument was used to collect household-level data from smallholder farmers in Zambia and Central Kenya. The work was undertaken in the context of two projects implemented by the International Centre of Insect Physiology and Ecology (icipe). The Insect for Feed II project, implemented in Kiambu County in Central Kenya was promoting the use of black soldier flies as alternative components in livestock feed. The invasive fruit flies in southern Africa project is addressing integrated pest management options to fight fruit flies in mango production. Both projects have a strong focus on integrating and benefitting women with their interventions. The pro-WEAI instruments were used in both studies to assess women's empowerment, to calculate the Pro-WEAI index and to identify context specific domains of dis-empowerment along the 12 Pro-WEAI indicators. Domains with high levels of dis-empowerment were identified to inform gender training and implementation activities of the projects. Although, dis-empowerment levels and the importance of specific indicators for dis-empowerment show some similarities in in the two project implementation areas, differences were identified and addressed in designing gender sensitive training and implementation activities. The poster presents differences and similarities in indicators and proposes intervention areas to be addressed by project implementers.

Keywords: Insect for feed, IPM, pro-WEAI index, women's empowerment

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Smallholder women farmers impediments in agriculture a risk to agro ecological farming success: a case of Makueni county, Kenya

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The agriculture sector is underperforming in many developing countries, and one of the reasons given is that it is because women do not have equal access to the resources and opportunities that they need to become more productive and face a lot more constraints than men in accessing productive resources. Women are also affected by cultural and social status. In rural areas, not only are women responsible for maintaining their households, but they also play a big role in agricultural production and increasing resilience to climate change. Yet, there are still knowledge gaps on whether existing solutions to climate change do work for women.

In a study seeking to understand gendered levels of adoption of Regenerative agriculture in Makueni County, Kenya, a mixed methods approach was adopted in which quantitative data (number of practices adopted) and qualitative data (semi-structured interviews) were collected from 96 farmers. Regenerative agriculture refers to the regeneration of soils through practices such as mixed cropping, minimum or zero tillage, cover cropping, crop diversification (use of legumes), crop rotation, composting, use of organic mulch, recycling of farm waste and integrated grazing resulting in sustainable and consistent crop yields. These practices are based on the principles of agroecology.

The results show that women faced systemic barriers in their ability to adopt these methods. Although the women are the ones who attended the trainings, patriarchal norms limited their decision-making ability to practices these methods, as they had to get permission from their husbands. For those who could adopt, they had little access to labour which is very critical in regenerative agriculture. For agroecological systems to work, women in agriculture need to be empowered to have greater control over decisions on resources, food production and time allocation.

Keywords: Agro ecology, regenerative agriculture, women

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Stochastic impact evaluation of a road water harvesting intervention in northern Ethiopia

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For efficient resource allocation and optimised returns from development interventions, decisions should be made based on detailed ex-ante evaluation. However, due to measurement difficulties, and a lack of appropriate tools to integrate the available uncertain information, such evaluation has often remained inadequate. Stochastic impact evaluation (SIE) presents a novel approach for evaluating complex development projects in the face of system complexity, uncertainty and variability. We used SIE to evaluate the viability of road-water harvesting interventions in the Tigray region of Ethiopia. After eliciting expert knowledge about the planned intervention, we generated a causal impact pathway model and collected estimates for all parameters. We used SIE tools, including Monte Carlo simulation, partial least squares regression and value of information analysis, to forecast project outcomes, identify sensitive parameters and detect critical knowledge gaps in decision-making. The experts identified percolation ponds, farm ponds, and check dams as suitable strategies for harvesting road-water. Model results indicated that the communities in the vicinity of the road are likely to benefit from road-water harvesting structures, while such measures are costly for the implementer. Harvesting flood water using percolation structures was found likely to generate positive impact with a value ranging between $18,000 and $120,000 per structure, while the overall benefits appeared negative for check dams. Harvesting road-water using farm ponds could generate positive impacts, but viability remains uncertain because of several knowledge gaps that should be narrowed by measurements before an investment decision is taken. This case study confirms the feasibility of using the SIE approach for analysing decisions on complex systems under uncertainty, suggesting broad applicability to similarly complex decisions.

Keywords: Climate smart road, check dam, farm pond, feasibility, percolation pond, simulation

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Voluntary sustainability standards and efficiency of coffee production: the case of smallholder producers in Honduras

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Sustainable coffee production has been believed to have the potential to enhance the economic, social, and environmental performance of farmers. However, coffee production is constantly under different economic, social, climatic, and international political pressure, which affect coffee production and therefore the living conditions of smallholder coffee farmers. Different Voluntary Sustainability Standards (VSS) indicate that their main goal is to improve the livelihood of smallholder coffee producers through certain pathways and practices that have to be adopted at the farm and household level. Using primary survey data of 659 certified and non-certified coffee producers in Honduras with data from the coffee year 2015/2016, this paper tries to determine the impact of VSS on the efficiency in the use of inputs and production of outputs, and the socioeconomic implications on Honduran smallholder coffee producers, against a comparable group of non-certified farmers, using Covariate Balancing Propensity Score (CBPS). Stochastic Frontier Analysis model for the production function is used to compute the Technical Efficiency of coffee producers. Preliminary results show that the mean technical efficiency is 51.6 % and 63.9 % for certified and non-certified coffee producers respectively, indicating the existence of a substantial inefficiency in the coffee production with the certified farmers. Despite that, certified farmers are found more profitable than conventional producers. The rate of return was found to be 2.9 % and 1.7 % for the certified and noncertified farmers respectively. Tobit model for the determinants of TE result depicted that age of household head, education level, land size, access to credit, distance to the plot and market, and decision making are among the main factors that significantly affect TE of both certified and non-certified farmers in either way. Based on the findings, enhancing education opportunities, better infrastructural developments for better market access and farm management, and expanding credit access opportunities could improve the efficiency enhancement of the study area. Additional models are being developed to robustness the analysis of this paper.

Keywords: Coffee production, efficiency, Honduras, smallholder coffee producers, stochastic frontier analysis, Tobit model, voluntary sustainability standards

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Crop index insurance: laying the foundation for more production decisions in drought-prone Uzbekistan

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Climate change challenges agricultural producers. This is most relevant for farmers in the Global South whose incomes are highly weather-dependent. In this context, overcoming rural liquidity constraints is fundamental to any agricultural investment decisions – whether agroecological or not – that can feed the world. Farmers need to decide for adequate climate adaptation strategies. Prominent examples are irrigation and drought-resilient seeds as agricultural inputs, and agricultural insurance in the field of microfinance. Intending to smooth incomes, uninsured farmers often decide for farming practices inducing stable but lower crop productivity. Growing evidence indicates that index-based insurance improves an efficient resource allocation and decreases ex-post losses. Since most studies did not differentiate between ex-ante and ex-post impacts, more research is needed to better understand its true implications. Our study is the first to examine the ex-ante and ex-post efficacy of crop index insurance in Uzbekistan. It enriches the index insurance impact research by focusing on resilience-increasing financial independency (credit uptake), agricultural investments (risky but higher return fertiliser use), and welfare-enhancing characteristics (household consumption, farm income). The basis of our analysis are framed field experiments that we conducted with 199 farmers. These sample farmers are located in Uzbekistan's pilot region for crop index insurance and are representative for rainfed grain farmers. They are the target population for the soon to be implemented real insurance product. Our results suggest that insured farmers are less dependent on external borrowing after experiencing drought, which increases their resilience. Further, index insurance (ex-ante and ex-post) stimulates investments in household consumption and (climate) riskier but more productive activities. While insurance coverage harms net income in good seasons, it allows policyholders to recover faster when encountering shocks. Our findings support the narrative that index insurance can increase climate resilience and productivity-enhancing investments that are essential for feeding a growing world population. Embedding this narrative into promotion activities may further boost (the often low) index insurance adoption and its synergies in the Global South.

Keywords: Crop index insurance, impact analysis, production decisions, resilience, Uzbekistan

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Farmland abandonment and its drivers on the urban-rural fringes of Ghana

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Farmland has suffered significant losses in many emerging countries because of rapid urbanisation, industrialisation, and economic expansion. Farmers are also diversifying their livelihood and becoming less reliant on farming and hence resulting in farmland abandonment. Agriculture is a key source of employment for close to 60 % of Ghana's population. As a result, depriving the sector of land in any section of the country causes an increase in unemployment and its eventual food crisis. This phenomenon would result in the possibility of food insecurity, and a low level of living standard due to farmers' low income. Hence this study investigates the determinants of abandonment of farmland in the rapidly urbanizing metropolis of Shai-Osudoku District in Ghana. About 142 semi-structured questionnaires were administered to farm household heads in five communities in the Shai-Osudoku District. Multiple linear regression was used to examine the effect of household, institution, farm, and location characteristics on farmland abandonment. The results revealed five key factors that had influence on farmland abandonment: off-farm income (0.018) $p < 0.05$, access to labour (0.040) $p < 0.05$, farmland size (0.003) $p < 0.01$, land disputes (0.063) $p < 0.10$, and distance from the farmhouse to the nearest urban area (0.038) $p < 0.05$. Based on the findings, the study recommended that Ghana implement an urban development policy to mitigate the harmful consequences of land-use changes on urban ecosystems in the Shai-Osudoku District and throughout Ghana. The purpose of such policies should be to maintain a reasonable balance between urban infrastructure growth, ecological sustainability, and agricultural productivity.

Keywords: Farmland abandonment, land tenure, land-use change, questionnaire survey, urban agriculture

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'Sin Pan No Hay Paz': Food sovereignty and (post) conflict in the rural Colombia. The case of El Valle de Tenza, Boyacá

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Social conflicts and internal wars affect food sovereignty. One of the main consequences of conflicts globally is hunger, especially in rural areas. Conflicts also affect decision-making, control, and use of resources in food production systems, which are essential elements of food sovereignty. This research addresses the link between food sovereignty and the armed social conflict in Colombia. The main objective is to identify the direct and indirect effects of the internal (post) conflict on the smallholder farmers' decision-making about their food production systems. The rural Valle de Tenza in Colombia is taken as a case study. The study consists of three main dimensions of research work. Firstly, identifying actors, institutions, and practices in the decision-making process with a focus on gender power relations. It is followed by identifying the effects of the armed conflict, which have influenced the smallholder farmers' decisions on their food production systems. The last dimension addresses the impact of public food policies and strategies on the region's traditional food production systems and consumption habits. This research considers food sovereignty and food security concepts equally helpful for hunger worries, especially in poor and rural societies. The theoretical framework builds based on the coloniality of power theory and the food regimes analysis, and the conceptual approach is based on food sovereignty. This study uses participatory research methods, including semi-structured interviews, key informant interviews, and focus group discussions for data collection. This research is currently in the data analysis phase after seven months of fieldwork in the Tenza Valley supported by the foundation *Fiat Panis* and MinCiencias. Considering Tropentag's academic space, I will present the preliminary results and research design. Finally, understanding the consequences of the armed conflict on food sovereignty contributes to formulating strategies under the current peace-building framework in Colombia. Furthermore, this study seeks to contribute significant evidence to the current global debate about food sovereignty and conflict.

Keywords: Coloniality of power, conflict, decision-making, food regimes, food sovereignty

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Unpacking the relationship among rural livelihoods, indigenous plant's cultivation and food security: Evidence from South Africa

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The neglect in the cultivation and utilisation of highly diverse indigenous plants poses a serious threat to food security status and rural development in the majority of the developing nations. Here, we (1) profiled the ethnobotanical and food security analysis of 31 selected indigenous fruits, grains and vegetables in South Africa and (2) estimated the determinants of cultivating indigenous plants and rural livelihood. The data utilized herewith relied on a survey from 31 selected rural areas of the North West Province of South Africa. Descriptive statistics and probit regression analyses were employed to achieve the research objectives. The study revealed that the total income made from the cultivation of indigenous plants was significantly higher among those who owe land than the participants who do not owe the land utilized for the cultivation of indigenuous plants in the study area. Likewise, the rural households that utilizes indigenous grains, fruits and vegetables had between 58–59 % probability of being food secured than their counterparts. Furthermore, the probit regression result indicated that land ownership, rural livelihood assets and ethnobotanical indices were the principal determinant ($p < 0.05$) of indigenous plants cultivation in the study area. We concluded that cultivation and consumption of indigenous plants was important for the food security of rural households. Therefore, policy interventions targeted at improving the present South Africa's land tenure pattern, awareness and indigenous plants farming incentives for more efficient and productive production have the potential to increase the plants wider acceptance, cultivation, rural livelihoods and food security in the marginalized communities of the country.

Keywords: Empirical modelling, food sovereignty, frequency index, rural development, undervalued plants, use-value

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Socioeconomic dimension of wild food plants use during the conflict in Syria

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Wild plants have served as a food source for humans since ancient times; the use of such food particularly increases when the availability or accessibility of conventional food is limited due to emergency situations, such as conflicts. Eleven years of the war in Syria have left a catastrophic impact on all life aspects, and it has caused the largest war-related crisis since the Second World War. Soaring food and fuel prices, stagnant salaries, loss of livelihoods and reduced food production have led to widespread food insecurity across the country. Nearly 60 % of the Syrian population (12.4 million people) are food-insecure. Our study aims to understand how people's socioeconomic status influences the use of wild food plants during the conflict. We hypothesise that with the decrease in household income, the use of wild food plants increases. We also hypothesise that the war-involved households (where a household member is a soldier, injured, or a victim) tend to have a higher reliance on wild food plants. The study was conducted in the coastal region of Syria between March 2020 and March 2021. Fifty informants (26 women and 24 men), representing 50 households, were interviewed in-depth on their use of wild plants during the current economic conditions resulting from the conflict. In addition to the qualitative analysis, a quantitative statistical analysis was performed using IBM SPSS programme version 27. Linear regression showed that the number of used species holds a strong positive correlation with informants' age, and a significant negative correlation with the annual household income. However, no statistically significant relationship was found between war-involved households and reliance level. Future analysis of a larger set of informants and further socioeconomic indicators is required to understand better how socioeconomic conditions influence the use of wild plants in crisis times.

Keywords: Economic crisis, Middle East, war-time food

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Impact of irrigation on rural farm household's nutritional outcome and potential irrigation-nutrition pathways in Kenya

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Increasing agricultural production in sub-Sahara Africa has been a key agricultural policy intervention not only for the region's governments but also for development partners and stakeholder involved. Irrigation has been advocated by researchers, policy makers and implementers as one of the plausible ways of increasing agricultural production in the region. With the evolving global agricultural policy arena this increase in agricultural production is aimed at addressing the regions food and nutritional insecurity and not to only increase caloric supply. However, the impact of irrigation on nutritional outcomes remain vague and largely understudied not only in the region but globally. This study undertook to study the impact of irrigation on the nutrition outcome of farm households using the minimum dietary diversity for women as a proxy for nutrition. It further hypothesised that the farm households can attain their desired nutrition outcome through the income, production and women empowerment pathway and as such extended the research to looking at the impact of the irrigation on these three potential irrigation-nutritional pathways. The study utilised data from a household survey 384 smallholder agricultural households in rural Kenya in 2021. The propensity score matching technique and the endogenous switching regression were used in the analysis due to their ability to address the potential endogeneity and selection bias of irrigating farmers. The results show that irrigation increases the dietary diversity of irrigating farmers by 0.43 points. On the three potential irrigation-nutrition pathways, the results indicate that irrigating farmers had a higher farm income of $1, 006, a lower production diversity of 0.39 points and there was no significance difference in women empowerment between irrigating and non-irrigating farmers. From the results we make a conclusion that irrigation does impact on nutritional outcomes of smallholder farmers. Nonetheless, there is a need for further analysis into the irrigation-nutrition impact pathways as the three potential impact pathways (income, farm production and women empowerment) have different impact effects.

Keywords: Endogenous switching regression, nutrition pathway

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REDD+ in the Philippines uplands: Opportunity or threat for indigenous peoples' rights and traditional livelihoods?

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All over the world, REDD+ projects are taking place on indigenous lands, in forests on which their livelihoods depend. REDD+ has often involved changes in traditional farming methods, with shifting cultivation blamed for being the cause of deforestation. REDD+ has been criticised for not sufficiently involving local communities in decision-making processes and for not rewarding them and indigenous peoples (IPs) protecting the forest with tangible benefits. A strong theoretical safeguard for IPs in the Philippines exists, and it lies in the respect of the "Ancestral Domain Sustainable Development and Protection Plan" (ADSDPP), a management plan that should be developed by IPs following the granting of their land title. The research reviewed the Philippines IPs' rights regime to identify whether it could effectively protect their rights and livelihoods in the context of REDD+ projects and enable IPs to access co-benefits. A qualitative, inductive, case study approach was superimposed on a rights regime approach to understand how IPs are able to uphold their rights, through their own point of views. Primary data collection was done through fieldwork in the northern part of the Philippines during which seven focus group discussions and thirteen key informant interviews with representatives of two indigenous communities having been involved in forest carbon projects were conducted. Findings of the research confirm that most indigenous communities still heavily rely on the forest and its resources for their livelihoods and basic needs (e.g. housing and fuel). IPs have hope that REDD+ will recognise the traditional "*kaingin*" system (shifting cultivation) as practised sustainably by IPs on their land and condemn the unsustainable "*kaingin*" as practised by others. The research highlights concerns about elite capture of REDD+ co-benefits, with lack of clarity remaining around its recipients and the channel mechanism and around the protection of IPs rights in a REDD+ context. However, the research showed that REDD+ in the country is an opportunity to promote IPs' traditional livelihoods, enhance IPs' ADSDPP, clarify the tenure regime, improve IPs knowledge of their rights and capacities to uphold them, revisit the role played by national institutions for IPs' rights protection and reinforce their capacity.

Keywords: Forest, forest carbon projects, indigenous lands, indigenous peoples, livelihoods, Philippines, REDD+, shifting cultivation, tenure regime

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Spatial and temporal dynamics of urbanisation and its impacts on flash flood risk: a case study from Jordan's wadi system

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Middle Eastern cities have experienced high rates of urbanisation since the second half of 19th century leading to high pressure on ecosystems ecosystem services and functions. Amman city of Jordan is a prime example on this, where the ongoing urbanisation trends also increases the risk of flash flood damages. There is still a lack of knowledge on the underlying driving forces and the complex interrelationship of land use and land cover changes (LULCC) and their effects on flash flood risk.
Therefore, this study aims to quantify the urbanisation dynamics in Amman city, its main underlying drivers, and its possible impacts on ecosystem services and functions to better understand the complex interactions between LULCC and risks from flash floods. An analysis of long- term LULCC from 1968 to 2021 using an object-based classification of multi-temporal Corona and Spot images was conducted. To investigate the underlying driving forces of LULCC and its possible impacts on the changes in flash flood risks, semi-structured experts interviews and participatory mapping with local stakeholders were performed. During the analysed six decades, the built-up surfaces in Amman's watershed increased up to 192 km^2. Urban expansion rates were high throughout the study period with a peak during industrialisation in 1970s and 1980s. Suburbanisation was prominent leading to major losses of Amman's watershed rainfed agricultural lands and retention areas. This resulted in a reduction in water infiltration and acceleration of runoff rates in wadis increasing both the likelihood of flash floods and the disposition of people and the environment to risk. The urban expansion and its pattern appeared to depend mainly on the high rates of population growth, land prices at the urban fringe, landowners' pressure on local authorities for the zoning and subdivision of lands as well as accessibility factors such as distance to major roads and nearness to urban areas. The situation was further aggravated due to weak land-use governance where only few investment-oriented plans focused on the transportation and city center were implemented. Given the current state, the expected increase in city's population as well as the expected climatic variability's challenges on flash flood risk, sustainable land-use planning for the whole watershed area incorporating adaptation measures to decrease flash flood damages are urgently needed.

Keywords: Corona, land use land cover changes, rain-fed agriculture, spatial analysis, urbanisation

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Determinants of climate change perception accuracy: Cross-country evidence from Kyrgyzstan, Uzbekistan and Mongolia

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Drought is a major threat to farmers in semi-arid and arid regions and its intensity is increasing under the global warming. Individual perception about climate risks may play important role in adopting mitigation and adaptation measures but international experience shows that individual perception might fundamentally deviate from objective changes. So far, little attention has been paid in the literature to understand farmers' accurate perceptions drought and its actual occurrence. On the other hand, with growing literature on smartphone technology usage in agriculture, there is a scare literature on the role of smartphone-based weather acquisition on accurate risk perception. Thus, the understanding the role of smartphone-based weather information acquisition on accurate agricultural drought perception can help policymakers, researchers and weather-service developers to integrate smartphone-based applications for agricultural drought mitigation. Therefore, this study aims at filling these gaps by analyzing: 1) the discrepancy between farmers' subjective perceptions of drought occurrence and actual drought occurrence and: 2) the role of smartphone-based weather acquisition on accurate drought perception. The analysis was based on a cross-sectional dataset of 2830 observations collected in Kyrgyzstan, Mongolia and Uzbekistan in 2021, areas in which the incidence of drought has intensified in these regions over the recent decades. SPEI index was used to measure meteorological drought occurrence and the impact of smartphone-based weather information acquisition on accurate drought perception was measured by Propensity score matching. The results of SPEI based assessment showed that 33 percent in Kyrgyzstan, 68 percent in Mongolia and 54 percent in Uzbekistan and accurately meteorological drought occurrence. The results of the Kernel matching (PSM) estimate indicated that smartphone-based weather information acquisition significantly influences the perception of drought accurately in Kyrgyz and Mongolian samples, and insignificantly in Uzbek sample.

Keywords: Drought risk perception, Kyrgyzstan, Mongolia, SPEI, smartphone-based weather information, Uzbekistan

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Migrants: the pull effect of rural industrial areas as seen from space

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Accessibility to raw materials, cheap labour and lenient labour laws make rural areas attractive to many industries in West Africa. The set-up of small-scale solid mineral industries is popular in rural West Africa. These industries are labour intensive and require small to large areas of land. This is just one of the examples of industrialisation taking place in rural areas. Nigeria is well known for its vast oil reserves, which in turn creates a lot of employment opportunities, especially for low-skilled workers, since many of the reserves are in rural areas. Ghana's southern western region has a wealth of gold, which has caused small-scale industries to spring up and led to an influx of people from more rural areas. In combination with proximity to mineral resources, this has led to rural industrialisation. This can be seen in the increase in the number of people in an area which indicates an influx of migrants. When this happens there's an upsurge in migration to rural areas, and pressure on land and water resources from agricultural activities, which affects the livelihood of migrants. This study seeks to identify migrants' behaviours to move to rural industrial areas in Ghana and Nigeria using remote sensing proxies. The method will use several remote sensing products such as Landsat, Copernicus datasets, Hansen Global Forest dataset, WorldPop and JRC-Global Human Settlement Layer dataset. The Random Forest classifier will be used to generate a Landcover map of the selected areas with Copernicus and Landsat datasets. The expected result will have the potential to demonstrate that Copernicus data, World Pop and Hansen Forest Cover data can be a useful proxy for population and migration studies. Moreover, the monitored significant changes in land use and land cover in the industrial areas compared over the past 20 years reveal certain trends of the industrialisation era in Western Africa. The research has the capabilities of producing effective and accurate methods for identifying the pull effects of industries in rural areas. This is essential for the implementation of policies for improved infrastructure, improved labour laws, good health and decent wages.

Keywords: Burkina Faso, Ghana, industries, migrants, Nigeria, rural areas

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Farmers' strategies for dealing with flood risks in Bangladesh

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Flood is an unavoidable phenomenon in many parts of Bangladesh due to the tropical-monsoon climate and the physical characteristics of a low-lying riverine delta. Farmers in flood-affected localities adopt different farm management measures to minimise the consequences of flooding. In-depth information of farming strategies practised by different group of farmers in different localities is crucial to ensure the effective design and implementation of weather forecast information. Some studies on farmers' flood coping and adaptation strategies, using survey methods covering a large number of farm households have highlighted the diversity in adaptation. However, less is known about the more detailed farming methods of farmers in response to floods. Using a qualitative approach, this study investigates existing farm management strategies in three flood-prone communities to mitigate against the negative impact of floods. The research was carried out in three villages of Islampur sub-district, of Jamalpur district, a flood-prone area with diverse farming practices. Data were collected through focus group discussions and semi-structured interviews with selected farmers, and observing different stages of farming activities.

The results highlight the ways in which farmers from these three communities use diverse farm-management practices to deal with flood risks. The three main strategies farmers employ are the use of different elevation levels of farm land, adjusting the timing and combinations of crops across the year and making field-specific crop and crop-variety choices. Farmers' decisions about which crops and crop varieties to plant are largely informed by three criteria: growth duration, flood resistance and the value of the crop. Moreover, the findings also show that farmers' decisions in one growing season have implications for the next growing season and thus also have a temporal dimension. This knock-on effect between the seasons implies that farmers' response to floods in one year already anticipates the flood risks of the following year.

Keywords: Farm management strategies, farming practices, flood, growing season

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Social innovation for agroecological transitions: Changing roles in multi-stakeholder collaborations for improved local food system development

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The concept of social innovation (SI) is recently gaining attention in agroecological transition research. SI comprises change of multi-stakeholders' relationships and social practices in agroecological transition initiatives, such as participatory guarantee systems (PGS). PGS are group-based local certification approaches to ecological production, aiming at changes in system operators' relationships (producers, consumers, facilitators) through new ways of organising, framing, and doing. First retrospective studies showed that established PGS encourage reconfigurations of social relations to implement alternative farming and food practices. However, the analysis of how SI evolves through changes in relationships requires perspectives 'from within' and 'in the making'. The concept of roles is suggested to assess required changes of individual roles (tasks, responsibilities, rights) and role constellations to provide new opportunities for multi-stakeholder collaborations. Since 2019, we address the above issues in an ongoing case study (Northern Patagonia, Argentina) on the transdisciplinary development of a PGS from a SI perspective. Based on a qualitative actor- and activity-oriented approach, the objectives of the study are to assess 'from within' and 'in the making' i) how the PGS development process facilitates SI; and ii) how changes of understandings and enactment of individual roles and role constellations between participating stakeholder groups shape the collaboration and potential success of SI. Preliminary results show that the PGS development facilitates SI, by addressing social needs and by implementing new social practices, such as developing agroecological process and product quality standards, control mechanisms, and multi-stakeholder governance structures. Participants are encouraged to question their own and others' roles and to enact role changes. Expected role changes of producers and consumers (become active and responsible managers and promoters of the PGS) were shared among all stakeholder groups in the dialogue phases (framing). However, in the implementation phases (doing), it turned out challenging to meet expectations of enacting modified roles. We found joint (re-) definition of roles and evaluation of limitations for enactment of modified roles critical to improve SI in PGS. Only then, conditions can be adapted for multi-stakeholder groups to enact roles differently, increasing the groups' room to manoeuvre to better meet SI aims in agroecological transition trajectories.

Keywords: Consumer-producer proximity, participatory guarantee systems, short food supply chains, transdisciplinary research

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Perception of COVID-19 and coping strategies by pastoralists in northern Benin

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Pastoralist communities in Benin have been facing several socio-economic, political and environmental uncertainties in recent decades. COVID-19 occurrence in such a context is hypothesised to be an additional uncertainty that will further insecure and destitute pastoralist livelihoods. This study aimed at analysing pastoralists' perceptions of the pandemic, its effects on their households and their coping strategies. To achieve this, quantitative data were collected from 126 informants from 42 pastoralist households purposively selected in two districts in northern Benin, N'Dali and Tchaourou. The data collected with a digitised questionnaire was analysed using descriptive statistics with SPSS software. Results showed that COVID-19 is not perceived locally as the priority issue by pastoralists. Lack of grazing (100 %), difficult access to water resources (96 %), restricted and unsecure mobility (94 %) and increased land conflicts (76 %) are the most important issues for them. Most of the respondents (72 %) believe that the disease is real, causing feelings of sadness "Bisserekpinin" (97 %), fear "Koulo" (97 %) and anxiety "Dioure" (95 %). Pastoralists did not feel direct effects of COVID-19, as they did not record any COVID-related contamination cases or deaths in their neighbourhood. However, they experienced side effects mainly due to response measures by policymakers. By hindering mobility of herders and livestock, COVID-19 was perceived to have reduced income (97 %), weakened existing social relationships (95 %), brought poverty (33 %) and induced misery (14 %). Women more than men (81 % vs. 5 %) expressed difficulties in marketing animal products as they depend on dairy economy. Coping strategies by pastoralists include modifying livestock keeping practices (79 %), using formal or informal financial mechanisms (24 %) and adopting new livelihoods (17 %). This study revealed that there are local, national or regional issues of greater concern than COVID-19 to pastoralists, who experienced only side effects of response policies. An in-depth study could be useful in resituating local pastoralism in its context of change and reform in order to better learn about the dynamics of uncertainty management by pastoralists.

Keywords: Benin, coping strategies, COVID-19, pastoralist household, side effects

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Assessing the level and determinants of food consumption among young African agripreneurs

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Despite food security interventions being implemented the last decades, food insecurity remains a serious issue among individuals and households in Africa. Relatively, the prevalence of food insecurity is much higher in East and West Africa, compared to other regions in the Continent. This study assessed the level and determinants of food consumption among young agripreneurs in the East and West regions, taking evidence from Kenya, Nigeria, and Uganda. A multi-stage sampling technique was used to sample 1435 young agripreneurs across the three countries. Individual food consumption was assessed following a 7-day recall method. The level of food consumption was assessed using the food consumption score (FCS) proposed by the United Nation World Food Programme. Also, the determinants of food consumption were identified using a logistic regression model. Results showed that food consumption was high among the agripreneurs, with an acceptable average FCS. Among other factors, food consumption was determined by access to extension services, credit, participation in the empowering novel agri-business led employment (ENABLE) technologies for african agricultural ransformation (TAAT) business incubation programme, having employees, access to market information, asset ownership, and land size. Based on these findings, efforts to improve food consumption and subsequently, the food security status of young agripreneurs should support access to extension services, market information, and access to land. Also, more investments should be directed towards developing need-based agribusiness incubation programmes such as the ENABLE TAAT and other existing programmes should be scaled beyond the normal time-bound period to continuously support young agripreneurs.

Keywords: Africa, determinants, food consumption, food security, young agripreneur

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Organic cotton - does it offer multiple benefits for farmers? A sustainable livelihood analysis in central India

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India is the largest organic cotton producing country worldwide: more than 100 000 farmers are growing organic cotton on an average field size of less than 2 ha. For many of them, organic cotton is an important cash crop and a key income source. But the production of organic cotton can provide benefits beyond the income, such as ecological or health benefits. The sustainable livelihood approach offers a framework to look at the complexity of organic farmers' livelihoods beyond the economic aspects. Different assets describe the resources people have at their disposal, and the combination of assets describes the individual livelihood. We conducted a livelihood survey with a total number of 90 farmers, 45 organic and 45 conventional farmers in the cotton-growing region of the Nimar valley in Madhya Pradesh, India. A project supporting farmers in growing organic cotton and providing further social support has longstanding engagement in this area. We have assessed factors of farmers' physical, human, social, natural, and economic capital. Using descriptive statistical analysis we assessed the differences between the two farmer groups. Organic farmers were found to have a stronger social network, perceived increases in soil fertility, and increased on-farm diversity. Economic factors, such as costs for agricultural inputs often remained the distinguishing aspect between organic and conventional farmers. Differences in their social and human capital might be attributed to the effects of the project activities in the region. To develop projects that empower small-holder farmers, it is crucial to understand not only the economic but also the social impacts of these projects. More research is needed to develop a framework to guide such livelihood analysis.

Keywords: Cotton, India, organic farming, sustainable livelihood analysis

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Food security impacts of indigenous agroecology: Circular economy of Apatani rice-fish co-culture in eastern Himalayas

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In the agroecological discourse, the promotion of indigenous production practices and resource recycling is often presented as a means to increase the ecological resilience of the food systems. The participation of indigenous peoples is also key to achieving the ambitions of the UN SDGs— of zero hunger and poverty alleviation. The Apatani tribe in the Apatani plateau situated in the central western part of the eastern Himalayas in India has been successfully managing their agro-ecosystems for almost 500 years. Their farming is an integrated system of paddy-fish co-culture (PFC) based on the 3Rs principle of the circular economy—re-cycling, reusing and reducing. Considering the uniqueness of these systems, in April 2014, Apatani Cultural Landscape was added to the tentative list of UNESCO World Heritage Sites. Although indigenous agroecological systems have been lauded as having high environmental efficiencies, they are still considered as low productive systems incapable of supporting household food and nutrition security. The value of quantifying the food security impacts of agroecological farming is well recognised, but notable gaps remain in the literature. Contributions focus on resource-use efficiency, crop yields, and income, with important research regarding circular economy and institutions, remaining under-represented. Using primary data collected from adopters and non-adopters of PFC from 120 households in the study area, we measured food security at the household level using the indicators: food consumption score (FCS), and length of rice grain self-provision period. An ordinary least square regression model was subsequently employed to explain the drivers of food security, which revealed the significant positive influence of the adoption of circular economy, agroecological farming, and indigenous local institutions on household food security.

Keywords: Apatani, Eastern Himalayas, indigenous agroecology, resilience

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Profitability and commercialisation

Oral Presentations

Posters

Sorghum participatory varietal selection: a citizen science approach with tribal farmer communities in India

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Citizen science has been advocated as a powerful tool to collectively develop and implement new technologies. The triadic comparison of technologies (tricot) approach is a recent application of this principle for participatory varietal selection. This methodology has shown to successfully accelerate the adoption of rice, wheat and bean varieties, as well as to identify environmental influences on the varieties' adaptation.

In this contribution, we present a first application of the tricot approach for sorghum participatory varietal selection with tribal farmer communities in India. Our study included 200 farmers from 20 villages, located in the Adilabad District in the state of Telangana. Following the tricot methodology, each farmer blindly tested three sorghum varieties out of a total of six. The farmers were instructed to use the management practice of their choice to reflect the diversity of their growing conditions. At the end of the experiment, farmers were asked to rank the tested varieties from best to worst for traits such as pest and disease resistance, grain yield, and general appreciation. Specific statistical methods for ranking data were used to determine farmers' variety preference.

We extended the tricot methodology by evaluating the influence of socio-economic background, environment, management practices, and culture on the varietal selection process. The farmers' cultural values were measured using an adapted version of Hofstede's Cultural Dimensions Scale. In parallel with the farmer trials in Adilabad, we also performed an on-station experiment with breeders, using the same design and methodology on a reduced number of plots.

The evaluation of the farmer data showed clear preferences for one to two sorghum varieties given the considered traits. Covariables like soil quality, type of farming (organic versus conventional), and cultural values, showed significant effects on the farmers' choices, which represents a unique case to illustrate the complexity of factors influencing farmer varietal selection. The comparison of farmer results with breeder choices showed agreement about the most suitable varieties, which provides a strong validation of the tricot methodology. Therefore, we showed the big potential of the tricot approach to address farmers' needs in this kind of complex context.

Keywords: Crop adoption, participatory varietal selection

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Agri FinTechs and financial inclusion: the role of digital tools in Latin America

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Since the term 'FinTech' was coined in the early 1990s, financial technologies and their applications to different sectors have dramatically evolved. In the agricultural sector, where financial suppliers often face high transaction costs, information asymmetry, and principal-agent problems, FinTechs can play an important role in improving the quality and scope of financial services, creating a more diverse financial landscape and ultimately extending financial inclusion to rural populations. In this study, we explore different types of digital innovations implemented by Agri FinTechs to promote financial inclusion in Latin America. Within a mixed-method approach, we compiled a database of 49 Latin American FinTechs and identified five types of business models using cluster analysis based on common products and services. Corresponding with these business models, we reviewed eight case studies from pioneering FinTechs in Brazil, Chile, and Colombia to compare their processes, systems, and organisational approaches to increasing the efficiency of financial transactions, improving market opportunities, and promoting financial inclusion. Our results suggest there are 5 clusters of Agri FinTechs in the region: (i)large-scale creditors, (ii) consumer-oriented marketplaces, (iii) farmer-oriented marketplaces, (iv) value-oriented crowd funders, and (v) agri-digital insiders. Furthermore, the study shows that the Agri FinTech landscape in the region is highly heterogeneous and that business models are designed around 6 digital products: credit provision, online marketplaces, insurance provision, digital payments, crowdfunding, and matching services. Within these products, FinTechs focus on different segments of farmers and have contrasting popularity among users. Our results further suggest that while FinTechs have the potential to increase financial inclusion, they could also exacerbate the financial gap in many regions as the rural population often lacks training with digital tools.

Keywords: Agricultural finance, FinTech, Latin America, mixed-method research

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Cocoa producers' perspective on sustainable sourcing practices and the relation to their direct buyers

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Chocolate companies increasingly implement sustainable sourcing practices to improve sustainability along cocoa supply chains (SSP). Past research has shown that the improvement of sustainability along supply chains highly depends on the relationships (i.e. trust, commitment, dependency and conflicts) between supply chain actors. However, this research has largely disregarded the perspectives of upstream farmers. Smallholder cocoa producers are key actors in cocoa supply chains and the target of many SSPs. Thus, we were interested in how they perceive these SSPs and their relationship with their direct buyers.

Semi-structured and qualitative interviews were conducted with 395 farmers and 9 direct buyers in two case studies of cocoa supply chains, from producer groups in Ecuador and Uganda to Swiss chocolate brands. The two case studies covered two different SSPs: an in-house sustainability programme and an organic certifications scheme. A buyer-supplier relationship (BSR) framework was developed to illustrate applied power types (i.e. mediated vs. non-mediated) within SSP and their influence on the BSR quality. A content analysis was structured along this framework to illustrate BSR quality from a cocoa producer's perspective.

Farmers saw several benefits and disadvantages and suggested various improvements to the SSPs. Results showed that farmers had high trust and commitment towards their direct buyers and did not feel very dependent on them. Conflicts mainly arose related to prices, lacking communication and support. While SSPs generally increased farmers' dependency on specific buyers, implementation with non-mediated power (i.e. training) seemed to keep dependency but also farmer commitment rather low. Findings suggest that training alone is not sufficient to establish and maintain a good BSR and higher commitment from the buyer's side would improve overall BSR. Training needs to be less theoretical and more practice-oriented to be of actual support for the farmers. Furthermore, adequate prices and advance payments would help farmers and intermediaries to take the required actions to improve sustainability within cocoa cultivation and processing.

Keywords: Buyer-supplier relationship, cocoa cultivation

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Seasonal seed scenario planning: a framework for matching supply and demand in smallholder seed systems

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Access to quality seed is a key input to successful smallholder farming and food security. Seed supply organisations, including private companies and public seed distributors, intend to supply farmers with sufficient seed of locally suitable varieties in a timely manner. But farmer demand for different varieties is not static. In drier years, for example, farmers are likely to demand more early-maturing varieties than in rain-abundant years. As seed suppliers cannot easily foresee demand, a mismatch between scheduled seed supply and varying farmer demand often leads to sub-optimal outcomes for both farmers and seed suppliers. Today, free online seasonal climate forecasts give an indication of expected rainfall quantities up to six months before the planting season. Seed suppliers can use this information to better anticipate farmers' seed demand at crop and variety levels. Seed distribution can then be adapted, for example, by shipping higher amounts of early-maturing varieties into regions expected to face a rather dry season. Because seasonal climate forecasts are no perfect predictions, however, being prepared for any type of season is important. In an iterative co-design process involving private and public seed sector stakeholders from Zimbabwe and Ethiopia, we have developed a systematic, yet simple and heuristic procedure to support seed supply planning. 'Seasonal seed scenario planning' involves a data-driven analysis of the expected demand for different seed varieties under alternative seasonal climates (dry/average/wet) and facilitates informed decisions about seed supply management on that basis. This decision-support procedure uses a ready-made Microsoft Excel workbook to provide foresight about upcoming seed demand based on a seasonal climate forecast. A workshop guide, facilitated by a detailed PowerPoint slideshow, then supports decision-makers at seed supply organisations in collectively debating immediate adaptations for better matching expected seed demand. By exploring the concept of seasonal seed scenario planning, seed suppliers may also recognise other opportunities for systematically preparing for alternative seasonal climates. Applying the procedure can help to better serve farmers' seed needs under climate variability.

Keywords: Climate forecasts, climate variability, decision making

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The effects of drought on inequality: Evidence from rural Mozambique

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This study analyses the distributional effects of an extreme weather event among poor rural households. Climate change increases the frequency and intensity of extreme weather events and climate shocks, causing adverse economic effects for many households worldwide. Low- and middle-income countries are disproportionally more affected when considering damages relative to GDP. While pointing to an important geographic inequality, such cross-country studies do not help us to understand the effect of climate change on the poor since society's poorest members contribute little to macroeconomic indicators. The effects of climate risks are unlikely to be equally distributed within a given country. Poor households tend to be geographically more exposed to climate risk, own assets that are more susceptibility to damage, while also being less able to cope with losses. Furthermore, affected lower-income households might lack the resources to sustain their livelihoods, potentially trapping them in poverty in the long term. Thus, understanding the within-country distributional effects of climate change is central for national level policy targeted at different groups within the country. Exploiting the quasi-random spatial variation in weather conditions and using a first-difference estimator to control for time-invariant household characteristics allows us to causally identify the effect of exposure to drought conditions on income inequality in rural Mozambique – a population particularly susceptible to extreme weather events. Our empirical analysis builds on two waves of a representative household panel survey collected in 2002 and 2005, which contain detailed information on agricultural and non-agricultural income of rural households. The socio-economic data is combined with the drought intensity measure derived from the Standardised Precipitation Evapotranspiration Index (SPEI) aggregated at the village level. Our analysis disentangles the heterogeneity in effects across income groups, distinguishing effects on total household income as well as agricultural and non-agricultural household income. Results show exposure to drought conditions has a significant negative effect on agricultural income among the poorest households whereas the effects for the rest of the population was significantly less negative. There is no detectable effect on non-agricultural and total income, suggesting that poor households have been able to partly offset the shock to agricultural income.

Keywords: Climate change, extreme weather event, household analysis, inequality, Mozambique, panel analysis

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Explaining farmers' income via market orientation and participation: Evidence from Kwazulu-Natal, South Africa

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Agriculture plays a critical role in livelihoods, employment, food security, poverty alleviation, socio-economic development, and environmental sustainability in developing countries. Studies show that product market participation by smallholder farmers in developing countries is very low. This has slowed down agriculture-driven economic growth and retarded the contribution of agriculture to poverty reduction in most rural areas. Moreover, the literature on commercialisation transformation of smallholder farmers makes little distinction between market orientation and market participation. This study, examined this distinction and analysed their determinants separately. Empirical evidence is meant to inform interventions needed at production and marketing levels. In addition, the study examined if market orientation and market participation translate into smallholder farmers' income. Using the sample of 332 farmers, the study estimated output participation index/market orientation index, and employed two-limit Tobit, and OLS regression model. The study was conducted in and around four irrigation schemes in KwaZulu-Natal. The findings show that socio-economic, institutional and production factors influence market orientation and participation differently. Moreover, cabbage farmers had a higher rate of market participation index (83 %) but very low in terms of market orientation index (38 %) suggesting that cabbage output market participation, market orientation, and farmers' income are explained differently. The study thus provides evidence that market participation is more important in explaining cabbage income compared to market orientation. Engaged more on the market participation rather than market orientation would help to develop general market management strategy that can eventually enhance farmers' income. This evidence calls for policy measures that focus on the concurrent interventions farmers markets such as building partnerships with the private sector and farmers' organisations among others. Also, supporting better agricultural inputs and services, thereby improving farmers' livelihood in growing rural areas.

Keywords: Cabbage production, farmers' income, market orientation, market participation, South Africa

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Price negotiation in camel milk trade: Analysis of bargaining power of camel milk producers in Kenya

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Camel milk enterprise is crucial to rural employment, and food and nutrition security among pastoral communities in arid North-Eastern Kenya. Despite evidence of the growing demand for camel milk outside the pastoral population coupled with development interventions, the enterprise is still characterised by low quality and inadequate access to the end market and price. Due to milk producers' over-reliance on market intermediaries, imbalance of bargaining power and information asymmetry are issues of critical concern in understanding the cost-benefit sharing. This study utilised cross-sectional data from camel milk farmers and traders, to estimate the bargaining power in trade. Regression analysis was used to explain the relative bargaining power and the ask-offer spread considering the effect of transaction characteristics and controlling for socioeconomic variables. Results indicate that bargaining power in the camel milk trade still rests with the traders. Access to end market price information and group membership was crucial in enhancing farmers' bargaining power of farmers. Local social networks are therefore crucial platforms for sharing price information among geographically dispersed producers. The effect of transacted volume was positive linked to gain from reduced transaction costs when procuring a large volume of milk from the same farm. The farmers' bargaining power is therefore high with large milk volumes. However, milk is a highly perishable commodity, and holding costs and risk of loss in anticipation of an improved price may not be reasonable. This could explain the missing effect on the ask-offer spread. The effect of distance to the milk assembly point implies that collective pooling at production can enhance the bargaining power. Variable costs such as transport can greatly benefit from such an arrangement. Further, improvement in road conditions in the expansive rangelands can benefit the bargaining power of farmers.

Keywords: Bargaining power, cooperative, intermediation, market, transaction

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Impact of participation on income of agricultural entrepreneurs: a case of youth employment promotion programme in Sierra Leone

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Income generated from agricultural activities plays an important role in household food security, especially in most developing countries. Agricultural entrepreneurship focusing on commercial and subsistence food enterprises contributes to gross domestic product (GDP) in sub-Saharan Africa (SSA), and is also an important determinant of revenue among rural households in most developing economies. The impact of participation in agricultural programmes has often been studied, however, questions still arise regarding participation of the youth in these programs. This presents a potential for Sierra Leone, with a predominantly young population, to reduce widespread poverty among youths through employment in agricultural enterprises. This study evaluates the influence of the youth employment promotion programme (Business Loop) on the income of agricultural entrepreneurs in three districts of Sierra Leone. Quantitative and qualitative cross-sectional data were collected from 134 youth agricultural entrepreneurs. We use the Heckman selection-correction model to estimate the effect of participation on income obtained from agricultural enterprises. The inverse mills ratio (IMR) is calculated from the selection equation which adjusts the outcome equation for any selection bias associated with participation, and nonparticipation due to unobservable characteristics. We controlled for demographic and socio-economic factors such as gender, age, household dependants, education and location. The results show that participation significantly increases income. This can be explained through the various components of the program, which include capacity building, for example, training in business planning and accounting, risk management, marketing of products, including technical training. Higher prices were also observed among business loop programme participants, possibly due to better access to the market. The analysis shows that participation of the youth in agricultural programmes increases their income from agricultural enterprises, hence contributing to food security. Therefore, policy strategies could focus on enhancing and strengthening agricultural extension advisory services as a pathway to improve knowledge and youth employment in agricultural enterprises. Tailoring such programmes to the needs of the youth would be necessary to improve youth participation in agriprenuerships.

Keywords: Agricultural entrepreneurs, Heckman selection-correction model, Sierra Leone, youth employment promotion program

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Sustainability indicators of the productive systems in the Ibirapuitã river basin, Brazil

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The success of a given society or community depends fundamentally on the ability to manage local natural resources to generate prosperity without degrading them over time. The sustainability attributes of production systems are considered for their relevance at the global level. Climate change and biodiversity loss are two of the most urgent issues of the Anthropocene. Agricultural development projects aim to find alternatives to maximise food production, but it is essential to integrate water management and energy generation after considering the local issues. In this project, the socio-economic-ambiental principle of the MESMIS acts indirectly on the sustainability attributes, whereas the indicators of the water-energy-food dimensions directly affects sustainable attributes. To represent the heterogeneity systems in the Ibirapuitã Catchment area, the characteristics of the different sub-catchments were used as references during the selection of properties, therefore, a total of 121 farms were sampled. The measures attributes were self-reliance, productivity, adaptability, stability, and equity. The average of all the properties of the basin suggested that the attributes reflect medium sustainability. The Self-reliance attribute had the highest value of 73 %, whereas the Equity attribute had a weight of 63 %, which was the lowest value. The farm with the lowest sustainability presented two indicators, namely equity and stability, at the low level with weightage of 48 % and 45 %, respectively. In contrast, the property with greater sustainability presents all the attributes in the quartile of high sustainability highlighted adaptability with 88 % and equity with 80 %. The sub-catchment that corresponds practically to the Ibirapuitã protect

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area presented the highest score with a value of 70.24 %. This sub-catchment only differed significantly from the Inhanduí and Pai Passo sub-catchments. The Mariano Pinto, Inhanduí and Pai Passo sub-catchments showed no major differences among themselves. These three sub-catchments are characterised by having larger properties and using agriculture in their production systems. The Pai Passo sub-catchment was the one that presented the lowest sustainability score, presenting the lowest scores in all attributes: Self-management (64 %), Productivity (68 %), Adaptability (61 %), Stability (64 %) and Equity (55 %).

Keywords: APA do Ibirapuitã, NEXUS-MESMIS, Pampa biome

Applying the nexus-mesmis methodology in the river Ibirapuitã catchment area, Brazil

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The divergent effects of globalisation seize the world into interdependent and connected economies and those that experience drastic consequences. The economic and social disparity between these two worlds intensifies bringing disseizes between strategies and ways to promote sustainable and inclusive growth. These discussions were guided by the World Economic Forum (2011), which indicated economic disparity and global governance failures as risks with serious impact potential to generate other problems. These two risks unfold into three risk groups, scored as an important agenda of policies and actions: the 'macroeconomic imbalances', the 'illegal economy' and the 'water-energy-food' (WEF) issue. The linked approach arises from the concern to think articulated actions, since a portion of policies, in the national and international spheres, end up bringing solutions to isolated parts of the systems, unbalancing their effects. The Nexus Pampa project brings the emergence of systemic, transdisciplinary and participatory approaches from the perspective of a specific regional reality, the Ibirapuitã River Basin, inserted in the Brazilian portion of the Pampa Biome. This region has suffered socioeconomic and environmental consequences resulting from the agricultural production model based on the maximum productive efficiency of internationalized commodities, bringing to the fore the need for an integrative approach between the WEF link. Thus, based on the MESMIS methodology, Nexus Pampa makes adaptations transforming the tripod of sustainability (social, economic and environmental), object of MESMIS evaluation, in the foundations of the WEF nexus, which represent the dimensions of NEXUS-MESMIS

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sustainability evaluation. With this approach aiming to represent the heterogeneity of the productive systems and land use of the Ibirapuitã River basin, 121 interviews were conducted. The three dimensions are significantly different from each other. The water dimension represents a high index (87.98 %), the energy dimension an average index (63.52 %) and the food dimension is very close to the minimum limit of the average index (50.47 %). The results obtained demonstrate the applicability of the NEXUS-MESMIS methodology in measuring the sustainability of the WEF triad in the context of the Ibirapuitã River Basin.

Keywords: Nexus WEF, pampa biome, productive systems

The impact of agricultural credit on the cattle inventory in Colombia: a spatial analysis

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The relationship between access to credit, agricultural production/ productivity, and deforestation represents clear challenges for sustainable development (i.e., the elimination of poverty, reduction of inequalities, increase of food security and stimulation of economic growth) and has been widely documented. The precise impacts access to credit has on cattle production levels and deforestation, however, have not yet been fully documented. The objective of this study is to analyse the impact of agricultural and livestock credit, among other variables, on cattle production (herd size) and annual deforestation rates in Colombia through spatial panel data models. For this purpose, we consolidated a departmental data panel for the period 2011 to 2020, based on information provided by several public entities. Our results suggest that, in Colombia, the relationship between access to credit and cattle production is significant and, depending on whether the total quantity of credits disbursed, or their amount are considered, can be either negative or positive. In addition, there exists evidence of spatial dependence, meaning that cattle production in a specific department is being affected by cattle production in a neighbouring department or by all the departments that make up the national territory. Regarding deforestation, we found that, although the number of cattle present in a department does affect its annual deforestation rate due to a poor coverage of intensive cattle ranching, there is no relationship between deforestation and the access to credit nor any spatial correlations. Based on the results, we provide recommendations for stakeholders that can help in the design of instruments for expanding the access to credit, improving cattle production and productivity, and fomenting sustainable production practices.

Keywords: Cattle, credit, deforestation, sustainability, sustainable intensification

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Mathematical programming for optimal sustainable growth in agriculture: Results of agricultural sector model in Syria

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Syrian agriculture faces multiple challenges that threaten the state of food security in the country. More than a decade into the conflict, food production is severely affected by the crisis outcomes like damaged agriculture infrastructure, disrupted food value chains, and fluctuation in food prices and exchange rates. Moreover, severe drought episodes have regularly hit the country which further weakened the agricultural sector. While relative stability is slowly returning to major parts of the country, the question that remains is what are the policy interventions that would not only help households smooth their income and help agriculture to recover from the conflict, but also promote sustainable growth in the post-war time in Syria? To address this question, the study adopts the agricultural sector model (ASM) as an analytical tool to simulate policy scenarios in the post-conflict era. The research was conducted in 2019 in Syria, where data was collected from 1,430 households distributed across the country. Gross margins and details about on-farm activities were collected, and data were analysed using GAMS software. The mathematical programming model assumes that Syrian farmers have the objective of profits maximisation subject to multiple constraints of fixed farm resources (land, water, family labour), collective constraints (roads and extension services and other exogenous features such as weather and distance from markets), and risks (stochastic events related to prices and yields). The model further depicts the technology used at the farm level (i.e. how much physical inputs and other resources are needed to cultivate one unit of land with a particular crop using the alternative technologies) and agricultural practices (rotations pursued, the existence of intercropping, and the presence of policy-imposed constraints or incentives). The model simulates different scenarios that mainly address the impact of different cropping patterns and the adoption of modern irrigation techniques on effective water use in agriculture in Syria. The results of this study have important implications not only for the successful cultivation of food crops but also for encouraging the use of sustainable technologies which ultimately results in better food security outcomes in the long run.

Keywords: Agricultural sector model, conflict, food security, mathematical programming, policy scenarios, Syria, water

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Leather and leather product exports and their contribution for economic growth in Ethiopia: a time-series data analysis

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This paper has conducted an empirical investigation of leather and leather product export and their contribution to economic growth in Ethiopia. The study employed a time series data, the period from 1984/85 to 2019/20. The data set was collected from the National Bank of Ethiopia, International Monetary Fund, Ethiopian Gumruk Commission, and World Bank. This study employed vector error correction model and Johanssen co-integration test for data analysis. The result indicates that the variables used in the study were non-stationary at level but they were found to be stationary at their first difference. The study also found that leather and leather product export, gross capital formation, and net financial flow have a positive association with economic growth and statistically significant association with economic growth in the long run. In the long run, improving leather and leather product export and net financial flow and labour force contribute to economic growth in Ethiopia. Increasing the volume of leather and leather product export and the improvement of the quality of leather products are increasing the demand of the people and improving economic growth. This finding is consistent with our objectives and research question sequences. This thesis ends with some policy recommendations. To maximise the gain from the sector the country should be cautiously allied to bordering countries, which plan and design in a sustainable way of export of leather products and pointing to escalation Ethiopian leather and leather products exports and should also increase its trading partner among African and world countries. The study mentions that the country should diversify the export of leather products by growing the variety of quality, design, and colours of the product.

Keywords: Ethiopia, economic growth, leather and leather product export, VECM

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What are the benefits of agro-climate service scaling?

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Agricultural practices and outcomes are strongly impacted by past and present weather and climate. Future climate change is expected to raise the frequency and intensity of weather extremes and increase climatic variation. The lack of timely and actionable climate-informed agricultural advice leads to significant input and yield losses, which can render investments in farming unprofitable. Development organisations in Vietnam have provided agro-climate services (ACS) to smallholder farmers on a limited scale. They advocate for the government to consider upscaling the provision of ACS, but a large-scale roll-out could strain the government's financial and human resources. Evaluating the merits of climate services is challenging, because weather and climate risks, as well as the benefits that information services may provide, cannot be derived from existing datasets.

CARE in Vietnam, a non-government organisation, has provided ACS in two communes in Dien Bien District since 2015 and they hope to see the intervention get scaled-up by the local governments in the years to come. In this study, we used a decision analysis approach to conduct an ex-ante cost-benefit analysis of four candidate interventions aiming to scale ACS in Dien Bien District, Vietnam. Our analysis was conducted in collaboration with CARE's project staff, Dien Bien government staff and other experts. Together we developed a conceptual model of the scaling-up of ACS to 23 communes in the whole Dien Bien district and later programmed this as a probabilistic simulation. The results indicate a very high chance (98 to 99 %) of the ACS interventions providing net benefits. With 90 % confidence, investments in ACS would return benefits between 1 and 16 USD per 1 USD invested. These benefits include improved yield, reduced losses in agriculture, fewer animal deaths, cleaner water, better health, reduced GHG emissions, and economic returns from improved gender equality.

We demonstrate the usefulness of decision analysis as a powerful tool, given the current dearth of methods capable of addressing data-scarcity, biases and uncertainties in valuing climate services. The approach provides support to uncertain and complex decisions in development planning.

Keywords: Agriculture, climate change, cost-benefit analysis, decision analysis, probabilistic modelling, uncertainty

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Peanut by-product as an energy source for improving peanut productivity

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Peanut is one of the essential proteins and oil crops that is mainly produced in arid and semi-arid areas. It is a cash crop that contributes to the economy of many countries in Asia and Africa, with an annual global production of 34 million metric tonnes on 24.39 million hectares of land. Its production is associated with the generation of residual biomass, often discarded or burned in the field, emitting greenhouse gasses. After removing the kernel, the pod amount to 20 – 30 % by weight of the dried peanut ends off in the landfill, thereby wasting the potential amount of energy feedstock. Due to their poor nutritional value, peanut shells have no potential to be utilised as animal feed. With a calorific value of 16 – 19 MJ kg^{-1}, the pods can serve as a promising feedstock for densified biofuel production, which may become a source of income for the next show. The seed can be used in raw or roasted form for peanut butter production and oil extraction. The oil extracted from peanuts is consumed for edible cooking in many countries. Peanut cake, 50 % of which is mainly protein, is used in preparing different meals and snacks for humans as well as feeds for animals. The research focuses on determining peanut shells' energy potential for densified biofuel production and their contribution toward improving peanut productivity. Most of the peanut processing is still carried out using fuelwood. However, the process can provide alternative energy that can be used for processing peanuts into different snacks, thereby reducing overdependence on fuelwood, especially in rural areas.

Keywords: Biofuel, peanut pods, peanut shells, renewable energy, residual biomass

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Economic analysis of wheat and milk value chains in North West mt. Kenya

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Agricultural activities have become increasingly organised along value chains that constitute actors and activities that cause the flow of food from production to consumption. This change has been necessitated by among other things, globalisation, the need to efficiently meet rising and changing consumer demand and preferences, and the need to meet quality standards. However, major concerns still persist as to the performance of agro-food value chains, particularly in developing economies. Evidence has shown that productivity remains low, mainly at production level. Profound changes of our current agro-food value chains are needed if they are to meet current and future demands. The study assessed the contribution of wheat and milk agro-food value chains to participating actors by establishing the value added and its distribution. Furthermore, the study analysed the structure of the value chains in terms of economic activities, actors, product flows and governance. Using multi-stage stratified random sampling, a sample of 206 respondents including producers, traders, processors, distributors, retailers and key informants were selected for the study. The study used value chain analysis to examine the structure, value addition and governance in the agro-food value chains. Results revealed that some actors add more value than others. Output, prices, costs and bargaining power are among factors determining value. Smallholder farmers have low yields, lower farm gate prices and low bargaining power. The governance structure of the agro-food value chains is heavily influenced by their marketing structure. The extent of vertical and horizontal integration differs in the value chains. Results revealed existence of multiple power centres within the value chains with large-scale farmers, traders and processors being dominant. There is need for more support to smallholder farmers who are the majority actors. Strategies focused on value chain upgrading should prioritise smallholders who are more constrained and benefit the least. Innovations and interventions should target such actors where the greatest impact on achieving improved productivity, incomes and efficiency can be achieved. Moreover, strategies that focus on building strong and resilient farmers associations have the potential of improving smallholders bargaining power and creating more inclusive value chains.

Keywords: Milk, smallholder farmer, value chain, wheat

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Assessing the relevance of traditional peasant markets for tuber landrace diversity and food sovereignty on the peruvian andes

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On the Peruvian Andes, traditional forms of agricultural production and commercialisation prevail, which offer prospects for conceptualising resilient and sustainable food networks. Ferias campesinas, i.e., peasant markets, are spaces of exchange where diversity of Andean tubers, knowledge, and practices are traded, representing an accessible direct marketing channel for peasant produce. An extensive network of ferias taking place regularly in rural villages and urban centres constitute an ancestral intra-ecological corridor, known as the Qhapaq Ñan, where agricultural exchange and barter from diverse geographies occurs. The COVID-19 pandemic has had a significant impact on Andean peasant economies, as severe mobility restrictions prevented farmers from reaching markets for selling and buying products essential for their subsistence. The shock of the pandemic, coupled with further economic, political, and environmental crises affecting the global food supply, including climatic changes as well as the drastic increase of fertiliser prices, impact production and marketing cycles and continue to push farmers into poverty. This study sets out to investigate ferias across eight regions of the Peruvian Andes in the aim of evaluating their relevance for peasant economies, landrace diversity, and food sovereignty. For this, we apply a multi-stepped research approach in which we (1) identify market-related vulnerabilities and farmers' responses to shocks, (2) measure the levels of tuber diversity prevalent in markets, and (3) assess the relevance of traditional peasant productive and marketing forms in the current shock scenario. This research generates empirical evidence comprising cartographic, quantitative, and qualitative data for understanding the significance of peasant markets. In that manner, we identify pathways for enabling the persistence of peasant productive and economic organisation forms over time.

Keywords: Markets

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The cashew nut value chain in Tanzania: opportunities for upgrading

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Cashew nuts have been an important export cash crop in Tanzania for decades, bringing hard currency, and being the mainstay of a large number of farmers' households. Despite recent improvements in crop management and a steady growth in crop production, the country, as well as others in sub-Saharan Africa, has been struggling to develop an internationally competitive processing industry. This results in a deepening of a colonial pattern of development whereby low-income countries focus on exporting raw agricultural commodities, leaving the higher stages of the value chain for middle- and high-income countries. Contract farming (CF) is an institutional innovation that has been extensively studied in a wide variety of contexts, however there is a literature gap on its implications to the cashew nuts value chain development, especially in the case of Tanzania. CF has been recently introduced in the country and, although it promises to improve the sector by directly connecting farmers with processing firms, it still has a number of challenges that need to be addressed with more targeted policies. Within this context, this article seeks to assess the effects of CF arrangements on farmers' welfare (income, crop production, food security, and subjective well-being) and on firms' competitiveness and access to international markets. In order to carry out this impact assessment, we employ the Inverse Probability Weighted Regression Adjustment (IPWRA) estimator as the methodology to control for endogeneities in tandem with an ordered Probit model to determine the factors of CF participation. After analysing sectoral secondary data, we explore primary data collected in early 2022 with key stakeholders from the Tanzanian cashew nuts sector. We find that farmers connected to processing firms are associated with higher welfare outcomes when compared to those that sell only in the traditional marketing channel. This article offers a compelling account of the development of the cashew nuts sector in Tanzania by identifying opportunities for value chain upgrading and the challenges that need to be tackled.

Keywords: Cashew nuts, contract farming, processing firms, Tanzania, value chain upgrading

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Analysis of drumstick (*Moringa oleifera* Lam.) value chain: a case of eastern Nepal

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Drumstick (*Moringa oleifera* Lam.) is categorised as an underutilised and neglected species in Nepal. Despite its nutritional value and potential for income generation, the production of drumstick is limited to backyard farming. Drumstick holds a huge potential in increasing the income of value chain actors, particularly farmers. The purpose of the study was to understand the roles and benefits of core value chain actors, as well as identification of the major problems in the production and marketing of drumstick in Eastern Nepal. A total of 148 drumstick value chain actors were interviewed to obtain the primary data, which ranged from the input supply to consumption. The major value chain actors were input suppliers, drumstick producers, local collectors (collecting drumstick from farmers and trading to local large markets), distributors (wholesalers, retailers) for delivering the drumstick to consumers, and ultimately, consumers. The drumstick is marketed mainly through the channel as "producers-local collectors-wholesalers-retailers-consumers". The marketing margin of drumstick was NPR. 60 per kg, and the producer's share was 53.8 % in the study area. Farmers perceived the diseases and pests as a serious problem during drumstick production, while marketing intermediaries perceived less and irregular supply of the commodity to meet the market demand as the major problem. Farmers were unaware of the appropriate method of pest management in drumstick production. Technical assistance for drumstick production practices, availability of quality inputs, and value addition can encourage drumstick farmers to propel from the backyard to commercial production. Coordination among the value chain actors and enablers is required to enhance the market information and price control mechanism for increasing the producer's share and strengthening the value chain of drumstick.

Keywords: Marketing, producers, production, value chain actors

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Financial feasibility of the drumstick (*Moringa oleifera* Lam.) enterprise in eastern Nepal

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Drumstick (*Moringa oleifera* Lam.) is an underutilised crop and limited to the backyard farming in Nepal. However, drumstick farming is considered as low investment enterprise with an immediate return. The study analyses the financial feasibility of the drumstick enterprise in the Terai belt of Eastern Nepal. The primary information was obtained from drumstick producers (105) through a household survey, interviews with the key informants (7), and conduction of the focus group discussions (3). Besides, relevant literature was reviewed for secondary information. Drumstick farming could be a viable enterprise for smallholder farmers in the Terai. The drumstick enterprise is economically profitable for continuous ten years of production plan. However, a comparison was made between continuous ten years (same plant) and each five years of production (new plantation in every 5^{th} year). The average Benefit Cost Ratios (BCRs) for continuous ten years and every fifth year plantation in drumstick production were 2.20 and 2.22 respectively. The Net Present Value (NPV) was NPR 6,870,992 and NPR 8,039,131 per hectare, and the Internal Rate of Return (IRR) was 127.1 % and 142.2 % for continuous ten years and each five years of drumstick production respectively. Drumstick enterprise was profitable even with the 10 % increase in total cost and 10 % decrease in total revenue during the production. The Payback Period (PBP) was 2.56 years of continuous ten year period, and 2.56 years and 2.38 years for each five year period of drumstick production. Therefore, an establishment of the new orchard every fifth year of drumstick production is more profitable compared to the continuous ten years of production from the same plant in the Terai belt of Eastern Nepal.

Keywords: Drumstick, investment, production

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Climate-smart millets production and its value-addition: an economic documentation from India

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Millets are climate-smart crops and they are sustainable solution for changing climatic conditions owing to their low water requirement, tolerance to fluctuating temperature, and gives assured yields. Millets are considered as 'Nutri-Cereals' whose consumption can help in alleviating malnutrition, reducing the risk of heart diseases, diabetes, high blood pressure, and many other modern lifestyle diseases. This study endeavoured with the aim of finding the profitability of selected millets *Panicum sumatrense* (Little millet), *Setaria italica* (Foxtail millet), and *Paspalum scrobiculatum* (Kodo millet) cultivation and their value-added products. The study was based in India with a sample size of 45 farmers who were cultivating millets and four women farmers who were involved in the value addition of millets for the agriculture year 2019–20. The results revealed that the total cost of cultivation per acre was Rs. 14,135.54 (184.72 USD) for little millet, Rs. 14,228.41 (185.94 USD) for foxtail millet and Rs. 15,339.77 (200.46 USD) for Kodo millet. The return per rupee of expenditure in small millets cultivation was found to be Rs. 1.31 (0.017 USD) in little millet, Rs. 1.20 (0.016 USD) in Kodo millet and Rs. 1.17 (0.015 USD) in foxtail millet. With respect to value-added products, the return per rupee of expenditure was higher in millet malt with Rs. 2.11 (0.028 USD) followed by foxtail millet papad (Rs. 1.64 / 0.021 USD), upma mix (Rs. 1.45 / 0.019 USD) and dosa mix (Rs. 1.40 / 0.018 USD). The return per rupee of expenditure in case of value-added products was quite high compared to the return per rupee of expenditure in small millets cultivation. This shows that in general, value addition in millets always helps in increasing farmers' income significantly. The current research highlights the value addition of millets to enhance farmers' income, tackle climate change, and ensure regional food and nutritional security. Thus, millets should be promoted for farmers' benefits, consumers' health, and climate resilient agriculture.

Keywords: Climate-smart millets, cost of production, return per rupee expenditure, value-added products

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Evaluation of the sustainability of the meliponicola sector in southern Ecuador using a sustainability index

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The need to have economically viable, socially inclusive and respectful of the environment production systems is a priority to guarantee the efficient use of natural resources. Also, sustainability assessments of these systems constitute a fundamental input to make adequate decisions about future investments or adjustments to those carried out. At a global level, meliponiculture has been recognised as an activity with great potential to promote sustainable development, particularly in rural areas of developing countries, due to the multiple economic, social and environmental benefits that this activity generates. This work proposes the construction of an index of economic, social and environmental sustainability for identifying effective strategies for the sustainable development of the meliponicola sector in the South of Ecuador. Ecuador has a great potential for the development of the meliponicola activity and has high rates of poverty, particularly in the rural sector. Using a questionnaire designed for the evaluation of sustainability indices, 326 stingless bee keepers were surveyed on their farms. 50 indicators were identified, 20 from the economic dimension, 12 from the social dimension and 16 from the environmental dimension, based on which a sustainability index was constructed that obtained a value of 0.21 out of the range between 0 and 1, denoting low sustainability in the sector. Among the dimensions evaluated, the environmental presented a better situation (0.33), with respect to social (0.14) and economic (0.14). The results of the study will help decision makers and non-governmental organisations interested in developing strategies and implement technologies and good practices that contribute to their sustainable development.

Keywords: Meliponiculture, stingless bee, sustainability index, sustainable development

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Value chain analysis of utilisation of pineapple residues: a case study from Costa Rica

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The management of agricultural waste in pineapple production causes severe financial, environmental, and social challenges for farmers and society in Costa Rica, world's leading pineapple producer. Despite research findings on pineapple plant residue (PPR) utilising options, environmentally harmful disposal persists as a common waste management practice. Research on the implementation of large-scale utilisation projects of PPR in Costa Rica is also lacking. Based on a value chain analysis, this study aims to investigate the barriers regarding utilising PPR in northern Costa Rica and address these gaps in research. On this basis, we analyse the pineapple industry network in Costa Rica to derive concrete recommendations for action. Semi-structured interviews constitute the research method of this paper to investigate explicit knowledge. A heterogeneous group of stakeholders from industry and government agencies participate in the interviews. The evaluation of the data follows the methodology of a Qualitative Content Analysis. We find that primary financial aspects pose an obstacle to implementing waste utilisation projects in practice. Other barriers include insufficient mindset, awareness, and lacking knowledge in society about the consequences of PPR management and the necessity for alternative recovery methods. External circumstances regarding inadequate infrastructure and immature technologies also lead to arduous conditions utilising pineapple waste in Costa Rica. The findings highlight the need for targeted policy measures to create an enabling environment for large-scale recycling of agricultural waste from pineapple production. Identified stakeholders from supporting organisations are particularly suitable for implementing these measures due to the extensive connectivity in the pineapple cultivation system. The findings could be valuable in developing an interlocking network to improve PPR utilisation practices.

Keywords: Agricultural waste, pineapple plant residues, waste utilisation

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Dairy input agri-entrepreneurs' practices and their effects on inputs uptake by smallholder farmers in Tanzania

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Dairy is a major sub-sector in most developing countries that are agriculture-based, and smallholder farmers dominate milk production in these developing countries at about 80 %. Tanzania is among these developing countries and has the fourth largest cattle herd in Africa with majority of cattle keepers as smallholder farmers. However, dairy productivity per cow has been consistently lower than the potential productivity amid the increasing population. Among the major reasons for this is lower uptake and utilisation of dairy inputs and service technologies. This is despite the existence of public extension services and research extension. Input agri-entrepreneurs are an alternative avenue of dissemination of information on inputs and inputs bundling, as they regularly interact with farmers at grassroots, and this has not been adequately exploited in literature. This study aims to determine the effect of business practices by input agri-entrepreneurs on uptake and use of inputs by smallholder dairy farmers in Kilimanjaro and Tanga, Tanzania. This study will employ a survey research design. Tanga and Kilimanjaro regions have been purposively selected since they are implementation areas of Maziwa Zaidi II project of International Livestock Research Institute. Random sampling method was used to determine the wards where overlap of input and service entrepreneurs and smallholder dairy farmers exist, and samples of smallholder farmers and input agri-entrepreneurs obtained. Systematic random sampling was used to select 780 farmers from these wards with a balance between the members and non-members of producer organisations. A latent class model will be used to determine homogeneous classes of input agri-entrepreneurs basing on the nature of practices they do to increase sales and clientele. These classes, and the farmers' socio-economic characteristics will be used to explain the uptake of inputs and services by these famers, using the ordinary least squares method. Findings from this study will influence policy makers to tailor focus to an alternative input market system that promote uptake and utilisation of inputs and technologies, and stakeholders to realign their focus towards alternative efficient channels that will catalyze input uptake and utilisation. This will contribute to improved market participation by dairy smallholder farmers and boost milk productivity.

Keywords: Dairy productivity, developing countries, input agri-entrepreneurs, input uptake, ordinary least squares, smallholder farmers, Tanzania

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Agroecology and power distribution within supply chains: Andean blueberry case in Colombia

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Political ecology approaches the processes of power distribution among the actors, which is essential to determine the possibilities and limitations that smallholders have within the food systems. It reconnects the research in agrifood systems with its political and ecological implications, opening a spectrum of questions related to power distribution, access to technology, and information flows. This understanding of the agrifood systems provides foundations for reinforcing the social sphere of agroecology, which as a social movement, emphasises the importance of social capital to lead collective action and scale up the knowledge and innovations generated through family labour, small and highly diversified farms. Thus, agroecology offers crucial elements by focusing on finding ways to generate changes in the institutional and political framework to guarantee food systems where smallholders have access to markets, technologies, and knowledge. This study considers the case of Andean blueberry producers in Colombia and the challenges and barriers that smallholders face in order to form supply chains framed in agroecological principles. It was found that the power configuration and the legal framework of the conventional fruit supply chains in Colombia impact the formation of agroecological supply chains, preventing smallholders of making decisions and forming alternative supply chains. Nevertheless, the success of this endeavour is expected if those communities are tied to a specific territory with common cultural patterns, have personal closeness, and family ties. For that, a collective action approach supported by the dimensions of social capital can re-signify and enhance the idea of forming smallholder supply chains for this novel fruit in Colombia.

Keywords: Agroecology, alternative supply chains, Andean blueberry, Colombia, power distribution, smallholders

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Social differences of red meat consumption during meat crisis and COVID-19 pandemic in Iran

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Red meat plays an essential role in Iranian cuisine, both as a source of protein and as an integral component in eating behaviours based on religious and cultural factors. Economic challenges, including high inflation and low incomes, have affected red meat consumption in Iran in the last decade. In early 2019, the sharp jump in red meat prices led to fundamental changes in the Iranians' dietary intakes. This price crisis was directly followed by the COVID-19 pandemic, which affected Iran's under pressured economy and food markets. This study investigated the changes in per capita red meat consumption in Mashhad, the second-most populous city and a centre of red meat production in Iran, during these two crises. Mashhad is capital of Razavi Khorasan's eastern province. The fieldwork was carried out with questionnaires in two stages in summer 2019 and spring 2021. In Mashhad, the city quarter of residence can reflect the social class of individuals. So, the primary data was collected within a survey of 296 participants (households), which were randomly selected in three different city quarters: quarter one (low-income), quarter two (middle-income) and quarter three (high-income). Stratified random sampling was used. We have studied the same sample in three different periods covering pre-crisis period (before early 2019), red meat price crisis (2019–2020) and COVID-19 pandemic period (2020 onward). As the assumption of independence of the observations is violated, we could not use the one way ANOVA. Therefore, repeated-measures ANOVA was applied for comparison. The data analysis shows that meat consumption decreased among the low-, middle and high-income groups after the price crisis. During the COVID-19 pandemic, the per capita consumption of red meat decreased among low- and middle-income groups, while it increased among the upper-class groups. Moreover, low-income groups were more than the other groups affected by eliminating red meat from their diet or substituting it with non-protein sources. As a conclusion, the two crises have increased food insecurity and weakened social sustainability. To help vulnerable groups, government and civil society need to develop targeted strategies that enable lower-income consumers to cope with nutrition shortages during crisis periods.

Keywords: Consumer, COVID-19 pandemic, food security, Iran, meat price, red meat crisis, social sustainability

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Institutions

Joint response to global crises – partnerships for research and development (GIZ/BMZ)

Joint response to global crises – partnerships for research and development

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The triple crises of conflict, COVID and climate change are dramatically exacerbating existing food security challenges with the strongest impacts felt by the poorest in Africa, the Middle East, and Asia-Pacific in previously unknown magnitudes. Protecting the most vulnerable, whom the food crisis threatens to hit hardest, means taking immediate, joint and coherent action. In order to strengthen their resilience and develop context specific solutions, research, politics and development cooperation must be involved. Only the involvement of actors from all three areas can make local, regional and global agri-food systems more sustainable.

This session will throw light on existing structures of partnerships for research and development from the BMZ perspective as well as from an international, European and German point of view. Speakers represent key institutions in the context of Agricultural research and development in its thematic broadest sense.

Germany holds the G7 presidency in 2022. As an answer to the current global food crisis, Svenja Schulze, Federal Minister for Economic Cooperation and Development (BMZ), together with the World Bank, have initiated a "Global Alliance for Food Security" (GAFS), launched in May 2022. Data, analysis, and up-to-date information drive evidence-based crisis response and inform swift political, financial and technical actions. Research is a key building block to support GAFS's advice and advance focus areas. While an immediate response is key, a long-term transformation towards sustainable agricultural and food systems remains necessary in order to make vulnerable countries resilient to future shocks and crises. BMZ pursues this goal with its core thematic strategy "Life without hunger - transformation of agricultural and food systems", supporting programmes to strengthen sustainable and resilient agri-food systems in order to reduce hunger and poverty, promote sustainable use of resources and build resilience to crises and shocks in partner countries.

BMZ is a strong supporter of the global research partnership One CGIAR, which plays a pivotal role in providing research for transforming food, land, and water systems globally. Collaboration between One CGIAR, national

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governments, and international organisations is needed to meet the strong demand for innovations and ensure their delivery, scaling, and impact.
EIARD (European Initiative for Agricultural Research for Development) is a European donor coordination platform on agricultural research for development (ARD). The platform aims to promote and implement coherent European policies and investments at international, regional and sub-regional levels in order to increase the impact of ARD, in particularly towards advancing on the SDGs.
ATSAF (Council for Tropical and Subtropical Agricultural Research) is the implementer of the Tropentag and brings together more than 300 scientists and development experts for internationally oriented agricultural and ecosystem research in Germany. ATSAF informs, promotes multidisciplinary research, networks members with cooperation partners, increases public awareness, intensifies communication, takes a stand and creates identity for all those interested in these issues, especially students and young scientists.
All speakers (Juan Luca Restrepo (CGIAR), Christophe Larose (EIARD, EC-INTPA), and Folkard Asch (ATSAF) will present their own perspective and experience and discuss how partnerships between research, policy and civil society can create synergies for a more effective, inclusive and demand-oriented research and development approaches that are required to address the challenges of the current global food crisis.

Keywords: Global crises, global response, networking, partnerships, research and development

AfricaRice

Oral Presentations

Posters

Molecular characterisation of rice collection using genomic tools and development of the AfricaRice *Oryza sativa* and *O. glaberrima* core collections

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AfricaRice genebank holds 21,724 registered rice samples, which includes the two cultivated species (*Oryza sativa* and *O. glaberrima*) and five African wild species (*O. longistaminata, O. barthii, O. punctata, O. brachyantha* and *O. eichingeri*). Approximately 88 % of the registered rice samples at the AfricaRice genebank originated within Africa, of which the African rice (*O. glaberrima* Steud.) represents approximately 17 % of the collection. The African rice accessions have adaptive or protective mechanisms for different abiotic and biotic stresses in the continent, but are generally characterised by a wide range of undesirable agronomic traits. Undertaking characterisation and evaluation of such a large number of accessions presents logistical challenges in addition to being resource intensive. AfricaRice genebank have developed core and mini core germplasm sets which comprise a smaller number of genetically diverse accessions that are primarily aimed at getting manageable number of samples that could be evaluated for multiple target traits of interest in multi-location trials. In AfricaRice, efforts to develop germplasm subsets started with the analysis of genetic variation and population structure of the entire *O. glaberrima* accessions using 9,990 SNPs polymorphic SNPs. Using the maximum length sub-tree (MLST) method we have created a mini-core subset of 350 accessions that captured 98 % of the SNP polymorphism with most of the genetic variation observed within the studied accessions, and represented the different maturity groups (early, intermediate, late), 19 countries, and eight rice growing ecologies in Africa. The *O. glaberrima* mini core, are grouped based on their tolerances/resistances to drought, iron toxicity, submergence, stagnant, flooding, rice yellow mottle virus, African gall midge, bacterial blight or their anaerobic germination. The process of developing core collections was extended to the *O. sativa* collection where 5,738 accessions were studied using 25,904 DArTseq based SNPs. Using MLST method, we identified a subset of 600 accessions to act as the AfricaRice Sativa rice core subset. These accessions captured more than 95 % of the SNP polymorphisms in the entire collection. The assembled sub sets forms an important resource that will play a vital role in supporting pre breeding and rice improvement programme of the research communities in the world.

Keywords: African rice, AfricaRice, core collection, DArTseq, genebank, *Oryza glaberrima*, *Oryza sativa*, rice, SNP

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History and achievements of 'smart-valleys': Farmers' participatory approach for sustainable lowland rice development in sub-Saharan Africa

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Africa Rice Center (AfricaRice) aims to achieve rice self-sufficiency in Africa. For this purpose, the enhancement of rice yield and expansion of rice areas are both crucial. Rice is water-consuming and vulnerable to water deficits compared to other field crops. The improvement of water management is a critical factor to enhance yield in rice cultivation and the expansion of lowland for rice should be made with water control. By targeting inland valleys which are prevailing in the lowlands of sub-Saharan Africa (SSA) and account for 190 million ha, Africa Rice Center has developed a Smart valleys approach, a participatory low-cost lowland development technology on a community base. The Smart-valleys approach can be applicable for both the improvement of water management in rainfed lowland rice and reclamation of lowland for rice-based systems with water control. From 2012 to 2020, the Smart-valleys approach was adopted by 14,027 rice farmers on 241 sites covering a total area of 1,615 ha. Adoption of the Smart-valleys approach increased farmers' yield by 0.9–2.4 t ha^{-1}, farmers' net income by 267–1,157 US$ ha^{-1}, food consumption score (frequency of consumption of different food groups by a household) by 4–10 points, and yield stability (assessed using the coefficient of variation (CV) of yields with lower CV value indicating higher yield stability) by 2–11 %. Increases in yield and yield stability thanks to Smart-valleys adoption were higher in areas with more rainfall amounts. We estimated that West Africa (WA) would be rice self-sufficient with 9 % of the total inland valley area developed using the Smart-Valleys approach. Enabling conditions for the large-scale adoption of the Smart-valleys approach included securing land tenure rights, strengthening farmers' capacity, availability of power tiller for land preparation and fertiliser, and higher paddy market price. Currently, the Smart-valleys approach has been validated and disseminated in eight countries in West Africa (Benin, Burkina Faso, Côte d'Ivoire, Ghana, Liberia, Nigeria, Sierra Leone, and Togo). Seventy-one percent of inland valleys exist in other sub-regions than WA. Including the Smart-valleys approach in national adaptation plans would increase farmers' resilience to climate change and food security in SSA beyond WA.

Keywords: Adoption, *Oryza* spp., productivity, sustainability, water

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Drivers of adoption and impacts of the improved GEM parboiling technology for rice value chain upgrading on livelihood of women rice parboilers in Benin

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Rice is a staple food for more than half of the world population and second cereal in terms of land area and third in terms of production. However, the simple rice grain is poor in nutrients, while the African country's malnutritional level is among the highest in the world. AfricaRice has developed and introduced a new energy-efficient and women-friendly parboiling system called 'GEM' to improve the quality of rice for better nutrition and income generation. This paper used endogenous switching regression model to assess the impact of the GEM technology on livelihood of women rice parboilers in Benin. The Foster, Greer and Thorbecke (FGT) poverty measure was used to compare poverty levels between households using GEM parboiling equipment against those households using traditional equipment. A total of 822 rice parboilers were randomly sampled and interviewed in Benin, in regions where the technology was introduced. Results showed that women parboilers have expressed high interest in the use of the GEM technology and have reported that it helps to increase the quality of their final rice despite the relatively high cost of the equipment. Parboilers have not only adopted improved parboiling method but also have innovated by coping the design of GEM technology to adapt traditional equipment. Parboiling activity was a profitable business for different equipment used but the GEM technology is the most profitable. Adoption of GEM increased women parboilers rice recovery rate and income. Based on the FGT poverty measure's specifications, a significantly lower poverty status of 26 % was found among households using the GEM technology. These results are supported by women perception that output rate, quality of milled rice and labour reduction are major advantages of GEM technology. Policy actions such as training of local fabricators and credit options are required to out-scale th GEM technology and contribute to post-harvest mechanisation in Africa for income generation and poverty reduction among women parboilers.

Keywords: Benin, GEM equipment, impact, nutrition, profitability, rice parboiling

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Upgrading rice value chains in sub-Sahara Africa: a current situation and a perspective to bring higher quality local rice to the market

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Rice value chains in sub-Sahara Africa (SSA) are characterised by a high degree of fragmentation and inefficiencies resulting into low productivity of locally produced rice and its low quality compared to the imported rice from other rice producing regions of the world such as Asia and the Americas. The quality issue could be one of the causes for the high percentage rates of the imported rice (52 % as of 2021) to the total rice consumption of 33 million MT in SSA. AfricaRice and her partners have been undertaking three post-harvest and value chain development studies in the region that are critical to informing interventions needed to reverse this situation. The studies are (1) Examination of rice quality traits demanded in rural and urban markets in West and East Africa. As of 2021, 1,213 white and parboiled milled market samples were purchased from markets in eight African countries. The results of the sample analysis and socioeconomic surveys have been translated into consumers' demands, which can be crucial information for varietal development and dissemination, (2) Valuation of quantitative and qualitative rice post-harvest losses (estimated at US$ 10.2 billion in 2021), identification of three priority areas for loss reduction and loss mitigation tools/technologies suitable for smallholders who are dominant in the region, and (3) Site-specific value chain upgrading that targets all five components of the value chain upgrading trajectory (process, product, functional, channel and intersectoral upgrading) to improve productivity, sustainability and nutrition. This paper summarises some of the key findings of these studies and provides a perspective on rice value chain development in the region.

Keywords: Consumer demand, post-harvest loss, rice quality traits, sub-Sahara Africa, value chain upgrading

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Development of specific SNP markers for identification of rice species conserved in AfricaRice genebank

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Some of the major challenges facing genebank managers and plant genetic resource scientists relate to taxonomic classification and labeling. Misclassification and mislabeling lead to errors in genebank operations, including those related to conservation, management dissemination and use of germplasm. AfricaRice's genebank team reported that 3.1 % of 3,134 accessions from four rice species (*Oryza glaberrima*, *Oryza barthii*, *Oryza longistaminata*, *Oryza sativa* spp. *indica* and *japonica*) were either mislabeled or misclassified, leading to the effective use of germplasm in various ways. Such errors have been reported in others crop species and error rates vary from 3 to 28 %. Most instances of taxonomic misclassification and mislabeling are due to human error during planting of material, characterisation of accessions for phenotypic traits, and misreading of the germplasm names. These types of errors can best be avoided by implementing routine genotyping quality control (QC) methods using low cost, high throughput and user-friendly SNP markers. We recently identified in several *Oryza* species/subspecies 224 diagnostic single nucleotide polymorphic (SNPs) markers based on DArTseq-based, next-generation sequencing technology, which can be used to rectify taxonomic/mislabeling errors. We converted them into Kompetitive allele-specific PCR (KASPar or KASP) assays and validated a subset of them for low-cost routine genotyping quality control (QC) analysis. Among the 224 diagnostic SNPs submitted to LGC Biosearch Technologies' service laboratory (Hoddesdon, UK). One hundred and fifty-eight SNPs produced working KASP assays and were tested on 80 accessions from five species/subspecies. Among these, 87 (55 %) clearly differentiated the species/subspecies, indicating the utility of these SNPs as diagnostics markers. The remaining 45 % were either monomorphic (20 SNPs), or polymorphic, but with no clear haplotype pattern, making them ineligible to serve as diagnostic markers. We validated these results using 65 of the diagnostic SNPs in 625 accessions representing the five species/subspecies. In sum, we recommend subsets of 24 and 36 SNP markers be employed for "rapid" and "broad" diagnostic activities, respectively, to clearly delineate *O. barthii, O. glaberrima, O. longistaminata, O. sativa* spp. *indica* and *japonica*.

Keywords: Rice

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Assessing the impact of farm diversification on household nutrition: Evidence of four sub-Saharan African countries

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Farm production diversity by farmers can be identified as a key strategy for improving dietary diversity. Yet, little empirical research has assessed the linkages of farm diversification and on-farm diet. This study aimed to quantify the impact of the farm production diversity on household nutrition and analyse factors affecting the farm production diversity and household nutrition. Two nutrition indicators were considered in this study: Household Dietary Diversity Score (HDDS) and Farm Diversity. Instrumental Variable Poisson regression was used to analyse the data to account for the count nature of the outcome variable. This model also allowed measuring both the determinants of farm production diversification and the linkages of farm production diversification and dietary diversity within the rice farming households. A total of 795 households were surveyed in four countries (Madagascar, Nigeria, Senegal and Rwanda). Results showed that positive and significant relationship between farm production diversification and dietary diversity in general. One-unit increase in farm production diversity, the household dietary diversity score increased by 0.05 ($p < 0.05$) in Madagascar; 0.08 ($p < 0.10$) in Nigeria; 0.07 ($p < 0.01$) in Rwanda; and 0.08 ($p < 0.05$) in Senegal. Higher level of education, engaged in self-employment, farming training, and sex of household were the key drivers of dietary diversity in the households of smallholder farmers. Similarly, higher levels of education, household size, total cropped area, and engaged in self-employment were the main factors affecting household agricultural diversification. The findings suggested that encouraging farming households to produce various crop and animal species can be an effective strategy to improve dietary diversity among smallholder farmers. However, this relationship is complex; it may be influenced by demographics and socioeconomic characteristics; institutional characteristics, and farm characteristics of households.

Keywords: Crop diversification, dietary diversity, food consumption, SSA

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Ex-post impact of the digital and personalized recommendations in rice production: a case study of RiceAdvice application in the Senegal river valley

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The rice sector in sub-Saharan Africa (SSA) is facing important constraints that need to be addressed to ensure sustainable economic development. Although good progresses were, especially in terms of increasing production volumes, SSA countries have not yet achieved food self-sufficiency in rice due to high yield gaps. In addition, rice consumption has become important for food security in many countries including Senegal. However, blanket recommendations of nutrient management still widely used in sub-Saharan Africa failed to account for the site-specific and socio-economic context of producers. The development of the rice value chain requires technological advances in rice production to increase yield while reducing environmental footprint. AfricaRice and partners have developed a decision support tool called RiceAdvice which enables to provide digital and personalized recommendations leading to higher smallholder farmers' efficiency. This study assessed the ex-post impact of personalized recommendations for rice nutrient management among farmers in the dry and wet seasons in Senegal. Data were collected from 1229 rice farmers in the regions of Dagana and Podor in the Senegal River Valley. Marginal Treatment Effect with parametric and semi-parametric specifications which allows to account for both observable and non-observable characteristics was used. Results showed that most rice farmers grew rice during the dry season in Senegal and the adoption of RiceAdvice increased their yield and profit by 4 % and 6 % respectively. Socio-economic, institutional and perception characteristics affect the adoption of the RiceAdvice by rice farmers. We conclude that the more targeted information to farmers can improve livelihood and prevent negative environmental effects.

Keywords: Personalized recommendations, profit, RiceAdvice, Senegal, yield

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Introduction of ratoon rice cropping systems using perennial rice to Africa

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Africa Rice Center (AfricaRice) has attempted to exploit intensification and diversification options for rice-based systems in Africa to improve the productivity and sustainability of rice cultivation, incomes of farm households and nutrition status of local people. As part of this effort, the centre evaluated ratoon rice cropping systems using new perennial rice (PR) varieties developed from the interspecific crosses between *Oryza sativa* and *O. longistaminata* by Yunnan University, China in AfricaRice's experimental fields in Côte d'Ivoire (Humid zone) and Senegal (Sahel zone) in 2020 and 2021. Ratoon cropping is an excellent labor-saving technology for intensification and enhancing opportunities of diversification if sufficient yield is obtained. Using five PR varieties – PR101, PR107, PR23, PR24 and PR25 – and one check variety (WITA9 in Côte d'Ivoire and Sahel108 in Senegal), which is a popular high yielding variety in each country, the following cropping systems were evaluated: (1) Transplanting + Ratoon + Ratoon and this cycle was repeated; (2) Transplanting + Ratoon + Ratoon and ratoon cropping was continued; (3) Transplanting cropping was repeated twice a year. For the two years, six, seven and four crops could be harvested in systems (1), (2) and (3), respectively. In the Humid zone, PR23 and PR25 showed highest cumulative yield for the two years in the systems including ratoon cropping, i.e. systems (1) and (2). In system (1) and (2), PR25 depicted the total yield over 26 t ha^{-1} and 21 t ha^{-1} in the 2 years, respectively. For the ratoon cropping in system (2), plant reestablishment rates of the PR varieties were always higher than those of WITA9. Superior yield performances of the PR to the check could not be seen in the Sahel zone. Ratoon cropping systems using PR23 and PR25 could be promising for the Humid zone in Africa. Milling and physicochemical characteristics were determined in both milled rice and parboiled milled rice in all PR varieties and WITA9. The grain quality characteristics of all PR varieties, except milled rice head rice recovery of PR101, were rivaling those of WITA9. In the palatability test conducted in Côte d'Ivoire, all PR varieties, except parboiled PR24, were acceptable.

Keywords: Africa, *Oryza longistaminata*, perennial rice, ratoon cropping

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BMEL session: Potentials and risks of agroecological farming for global food and nutrition security - a panel discussion

Panel discussion: Potentials and risks of agroecological farming for global food and nutrition security

Maja Clausen

Federal Ministry of Food and Agriculture (BMEL), Division 123, Research and Innovation, Coordination of Research Area, Germany

The BMEL is committed to the development of sustainable and resilient food systems worldwide and the implementation of the human right to adequate food.
As part of this commitment, BMEL has established the funding instrument "Research Cooperation for Global Food Security and Nutrition". The focus of this instrument is on promoting practice oriented trans- and interdisciplinary research projects. The projects contribute to generating needs-oriented knowledge and the further development of capacities on the ground. The Federal Office for Agriculture and Food (BLE) acts as project executing agency.
Funded projects within this scheme strengthen the German contribution to sustainable food systems in partner countries through agricultural and nutritional research and by building long-term partnerships between agricultural and nutritional research institutions in Germany, Africa, South and Southeast Asia.
From BMEL's perspective, agroecological approaches can contribute significantly to the transformation process towards more sustainable food systems. Accordingly, agroecology forms a central component of the new 2022 call for research proposals on "Innovative Sustainable Production Systems". In the BMEL-Session, an expert panel will discuss the various facets and research needs regarding agroecological concepts and practices:

- Dr. Marc Cotter, Senior Scientist, Department of International Cooperation, Group Resilient Cropping Systems, Research Institute of Organic Agriculture (FiBL)
- Dr. Amy Faye, Post-Doctoral Researcher, Center for Development Research (ZEF)
- Patricia Nanteza, Science Writer, International Inst. of Tropical Agriculture (IITA)
- Dr. Stefan Sieber, PD Associate Professor, Humboldt University Berlin; Head of Department "Sustainable Land Use in Developing Countries", Leibniz Centre for Agricultural Landscape Research (ZALF)

With keynote speeches from:

- Dr. Samira Amellal, CropLife Africa Middle East
- Nivedita Varshneya, Country Director, Welthungerhilfe India

Keywords: Agroecology, food and nutrition security, Global South, international research cooperation

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