

# Tropentag 2018

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

## **Global food security and food safety: the role of universities**

Book of abstracts

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# Preface

We are pleased to present in this book all the abstracts that are being presented both orally and as posters at the 2018 *Tropentag* Conference that is organised for the first time in Belgium at Ghent University. This conference forms the culmination of a whole year effort by a wide team of committed collaborators both in Belgium and Germany.

*Tropentag* is an annual, international conference on tropical agriculture, food security, natural resource management and rural development. It is the largest European interdisciplinary conference on research in (sub)tropical agriculture and natural resource management. It rotates between universities and research institutes in Berlin, Bonn, Göttingen, Hohenheim, Kassel-Witzenhausen, and since 2014 Prague and Vienna. Tropentag 2018 is organised by Ghent University, Belgium (predominantly the Faculty of Bioscience Engineering - Department of Plants & Crops, Laboratory for Tropical and Subtropical Agriculture and Ethnobotany, and the Africa Platform of Ghent University Association), jointly with the Council for Tropical and Subtropical Research (ATSAF e.V), in cooperation with the GIZ Advisory Service on Agricultural Research for Development (BEAF). This year's theme of the conference is 'Global food security and food safety: The role of universities', but the numerous sessions and workshops cover a much broader range of subject areas that all centre/focus on 'tropical agriculture'.

Agriculture deals with the cultivation and breeding of animals, plants and fungi for food, fibre, biofuel, medicinal plants and other products used to sustain and enhance human life. Its prime vocation is and should be to sustainably maintain and – where needed and possible – significantly improve the nutrition and health situation of people around the world. Hunger, malnutrition, and poor health are global, and increasing development challenges. Agriculture has made remarkable advances over the last decades in increasing quantity and quality of food and other produce, but its contribution to improving the nutrition and health of poor farmers and consumers in developing countries often still lags behind. In cases where food provision is structurally guaranteed, food quality may still be a problem. Agricultural research and universities have an important role in addressing and solving both food security and food safety. They should do this in collaboration with national and international governmental and non-governmental donor and policy-oriented organisations, with respect

for local, regional and global socio-economic and cultural situations, legal conditions, markets and market mechanisms, limitations and opportunities, gender equity and the natural resource environment, in order to provide for sustainable solutions.

The conference theme is addressed in plenary keynote lectures and in presentations and poster contributions organised in 24 thematic sessions. This year a special emphasis will be given to ‘agriculture for nutrition and health’ with contributions of this year’s CGIAR feature research project A4NH (see: [a4nh.cgiar.org](http://a4nh.cgiar.org)), as indeed we opted for featuring a program rather than a centre as the CG system itself is organising itself much more than before around federating themes that bring together CG centres but also partners from academia and research *sensu lato*.

All in all, we received some 960 abstracts addressing these issues. This book contains about 340 poster abstracts, and 110 abstracts for orals, whereby a big portion is in line with the conference’s theme. The role of universities, or academia in general, apparently inspired a lot of scholars. Additionally, you will also find the keynotes’ abstracts.

We hope that the scientific contributions in this book will help you to broaden your knowledge, and find answers to a number of important research and development questions and to the conference theme. We wish you an enjoyable and rewarding Tropentag!

For the organising committee of *Tropentag* 2018

Prof. dr. ir. Patrick van Damme  
Ghent University

Ghent, September 2018

# Message from Minister Alexander de Croo

All too often these kinds of introductory words start with Malthusian predictions of impending doom: hunger in Africa is on the rise, climate change poses a major threat to food security, food production will not keep up with world population growth,... And I could go on for a bit longer.

And although these challenges are real, rarely do we look at where we come from and what we have achieved so far. While the world population increased at a rapid pace the prevalence of stunting has decreased from 40% at the beginning of the '90s to 22% in 2017. Despite population growth the number of food insecure people living in the world is predicted to further decline from 782 million people in 2018 to 446 million people in 2028.

Global awareness about the importance of nutrition, food security and food safety has increased enormously. Where the concept of 'nutrition' was only used by some food experts in the past it has been mainstreamed and adopted by agricultural experts, politicians and the like. In 2015, the UN Sustainable Development Goals enshrined the objective of "ending all forms of malnutrition" by 2030. And while a generation ago food safety was rarely talked about and even less analyzed, nowadays authorities from Beijing to Brussels to Abuja are being held to account when food safety standards are not being met.

Another positive development is the fact that in recent years both governments, the private sector and farmers have woken up to the abundant opportunities of investments in the agriculture and food sector. Agriculture is Africa's largest economic sector. More than one-quarter of the world's arable land lies in this continent, but it generates only 10 percent of global agricultural output. There is huge potential for growth. New ways of financing, through public-private partnerships, are currently rolled out.

If we would focus entirely on the challenges in food systems we might say 'the future is bleak'; but if we would focus on all the opportunities at hand to meet the SDGs we might say 'the future is bright'. In order to achieve our goals, in order to achieve more sustainable food production and better food safety we will need new and better ways of working. We will need to work better together, across disciplines, across cultures,

across institutions. Science and evidence based decision making should be at the center of all our efforts. Therefore this year's theme of Tropentag 'Global food security and food safety: The role of universities' could not be more appropriate!

May the backdrop of the medieval city of Ghent inspire us all to come up with new ways of working towards a future in which safe, nutritious and sufficient food for all people, in particular the poor and vulnerable, becomes a reality.

Alexander de Croo

Minister of Development Cooperation, Digital Agenda, Telecom and Postal Services,  
Belgium

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## The Myth about Organic Farming in Africa and What it Could Be

BERNHARD FREYER

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

The current debate about organic smallholder farming in tropical and subtropical environments includes more myths than facts about organic farming. One of the dominant misconceptions is that most African smallholder farmers already practice organic farming by default. Having a closer look what makes organic farming specific teaches us that the latter is not the case. What makes organic farming is the integrative approach of high organic matter input via forage legumes, alley cropping, hedges, farm-yard manure and compost, the exclusion of non-natural pesticides and herbicides, and a limited and partial exclusion of mineral fertiliser. Eco-intensification, (comprehensive) conservation agriculture, low external input, integrated agriculture, traditional agriculture, climate smart / sustainable agriculture, agroforestry / alley cropping or agro-ecology - in all agricultural methods some of the techniques of organic farming can be found, but mixed up with non organic farming techniques and inputs. Even there are quite some organic smallholder farmers certified in Africa, many questions remain open about the organic approach that are e.g.: How sustainable is the current organic smallholder farmers practice? Are there ecological, technical, economic or cultural barriers to organic production? How to convert a smallholder farm toward organic? And finally how far organic smallholder farming is able to contribute to “feed the world” and to the SDGs? The presentation will offer some answers to these questions and critically discuss the potential of organic farming in Africa.

## **Agriculture Can Improve Nutrition: How Can Countries Leverage Agriculture, Linking with Other Sectors, to Improve Nutrition**

NAMUKOLO COVIC

*International Food Policy Research Institute (IFPRI), Poverty Health and Nutrition Div., Ethiopia*

It seems intuitive that agriculture should improve nutrition, but evidence has shown that this requires deliberate efforts to attain. There is a mismatch between agriculture productivity improvements, and nutrition and health outcomes across low and middle-income countries. Research and programme evaluations have demonstrated that agriculture can indeed improve nutrition when integrated and designed with specific nutrition objectives and sensitivity. The keynote focusses on a synthesis of what we know, challenges and opportunities based on available evidence. The CGIAR Collaborative Research Programme on Agriculture for Nutrition and Health (A4NH) is used as an example to explore opportunities for synergy.

Before 2013, reviews on agriculture and nutrition were largely inconclusive showing little evidence that agriculture can improve nutrition outcomes. This in part due to poor design of projects/programmes making them difficult to evaluate, but also due to lack of specific nutrition objectives. Since 2013 additional evidence has emerged demonstrating that agriculture can indeed improve nutrition for integrated nutrition sensitive agriculture projects/programmes. Beyond key agricultural inputs such as supplying biofortified or nutrient-dense foods, key elements include women's empowerment, targeting, improved programme implementation, nutrition education and enabling multi-sectoral action.

However, how can countries leverage this knowledge, working with other sectors to create stronger linkages with nutrition and health? A4NH work on Leveraging Agriculture for Nutrition in South Asia (LANSA) and East Africa (LANEA) has shown that building commitment and translating commitments into action and impact requires attention to evidence (both data and related perceptions), policy, politics and governance; and capacity and finance. Ethiopia, Zambia and the Comprehensive Africa Agriculture Development Programme (CAADP) are used as case studies on challenges and opportunities for country led action. The case studies show different examples of what works and what doesn't and how a programme such as A4NH can support country performance in a more systematic and rigorous way.

## **Food and Nutrition Security: The Need for Science Based Coherent Policies and Actions**

STINEKE OENEMA

*United Nations System Standing Committee on Nutrition, Italy*

The United Nations declared the period 2016–2025 the United Nations Decade of Action on Nutrition. This means the world has been given a period of 10 years to intensify policies, programming and actions to achieve the global nutrition targets as well as accelerate the achievement of the Sustainable Development Goals (SDGs). During my presentation I will explain the need for policy coherence for nutrition and how the UN SCN works to achieve this, as well as give examples of gaps in knowledge where universities and research programmes could play a role to help address knowledge gaps, specifically when it concerns transdisciplinary research. I will also provide examples of how scientific knowledge helps to shape policy discussion.

## **Towards Sustainable Food Systems for the 21<sup>st</sup> Century: The Potential of Diversified Agroecological Systems**

EMILE FRISON

*International Panel of Experts on Sustainable Food Systems (IPES-Food), Italy*

Today's food and farming systems have succeeded in supplying large volumes of foods to global markets, but are generating negative outcomes on multiple fronts: wide- spread degradation of land, water and ecosystems; high GHG emissions; bio-diversity losses; persistent hunger and micronutrient deficiencies, the rapid rise of obesity and diet-related diseases; and livelihood stresses for farmers around the world. These problems are tied to the industrial model of agriculture that is increasingly dominant around the world. The uniformity at the heart of these systems leads systematically to negative outcomes and vulnerabilities, and particularly the use of an increasingly narrow pool of animal breeds and plant varieties. The 'Green Revolution' of the post-war period left a dual legacy: huge advances in the productivity of staple crops, and the concurrent marginalisation of whole swathes of foods, crop varieties - and the communities depending on them.

The low-diversity industrial model is locked in place by a series of vicious cycles. Highly compartmentalized approaches to research, education and policymaking allow one-dimensional productivity-focused solutions to prevail, and obscure the links between healthy ecosystems, a healthy planet and healthy people. Meanwhile, the way food systems are currently structured allows value to accrue to a limited number of actors, reinforcing their economic and political power, and thus their ability to influence the governance of food systems.

To break these cycles, a fundamentally different model of agriculture is required, based on diversifying farms and farming landscapes, replacing chemical inputs, optimising biodiversity and stimulating interactions between different species, as part of holistic strategies to build long-term fertility, i.e. 'diversified agroecological systems'. There is growing evidence that these systems keep carbon in the ground, support biodiversity, rebuild soil fertility and sustain yields over time, providing a basis for secure farm livelihoods and diverse healthy diets.

## What Is Going Wrong with Agricultural Research in Africa?

FRANCOIS STEPMAN

*Platform for African - European Partnership in Agricultural Research for Development (PAEPARD), Belgium*

The book “What is the matter with African agriculture” (Henk J.W. Mutsaers, Paul W.M. Kleene (eds., 2012, 384 pages) brings together the views of a non-trivial sample of agriculturists from many walks of life. It discusses the achievements, failures and challenges of African agriculture and the role played by foreign aid in that story. Fourteen (40) “veteran” authors, divided between 22 Anglophones and 18 franco-phone, were invited. They answer three questions: (a) Why did we perform so poorly in our activities for agricultural development in Africa? (b) What are the most important drivers of change (social, political, technical) for more productive and profitable agriculture to flourish? (c) To what extent could reorientations in international policy and development aid improve the situation?

Recent reports and international events identify new drivers of change and calls for urgent action.

The interest of development cooperation for agricultural research projects has its ups and downs. The academic world and the development world still seem to operate in different spheres and a collaboration is still challenging due to lack of impact of such research. There is a growing call by research funders and development actors for impact of solutions at scale. This requires new ways of working together. In addition, there is an ever-increasing expectation for African agricultural research to create jobs and decrease the dependency on food import.

The context in which jobs have to be created and agribusiness developed is also changing rapidly. The changing farm size distribution in sub-Saharan Africa (especially in the 5 to 100 hectare range where the number of these farms is growing especially rapidly) reflects the increased interest in land by urban-based professionals or influential rural people. Given current trends, medium-scale farms will soon become the dominant scale of farming in many African countries. This suggests a new and hitherto unrecognised channel by which medium-scale farmers may be altering the strength and location of agricultural growth and employment multipliers between rural and urban areas.

Medium-scale farmers will increasingly dominate farm lobby groups, who add value to agricultural produce and influence policy making and public expenditures to agriculture in their favour. They will ask for research on processing and packaging food and African universities to focus more on farming technology.

# Plants and crops

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# Cropping systems

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## Grain Yield and Yield Variability of Rainfed Lowland Rice with “Good Agriculture Practices” in the Kilombero Floodplain of Tanzania

JULIUS KWESIGA<sup>1</sup>, DANIEL NEUHOFF<sup>1</sup>, GEOFFREY GABIRI<sup>2</sup>, KRISTINA GROTELÜSCHEN<sup>1</sup>, KALIMUTHU SENTHILKUMAR<sup>3</sup>, ULRICH KÖPKE<sup>1</sup>, MATHIAS BECKER<sup>1</sup>

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Rainfed lowland rice is commonly produced by smallholder farmers in the floodplains of Tanzania. Erratic rainfall and uncontrolled flooding by spill-over of the river create conditions of unpredictable hydrology. Combined with a low N content of the predominant Fluvisols, N deficiency and unfavourable hydrology are major factors limiting rice production in floodplain environments, and can result in large yield variabilities. The variable and hence unpredictable outcome of farmers' investments is a major disincentive for adopting improved agronomic practices. We investigated rice crop management strategies that improve the use efficiency of water while adding the limiting N regrading rice grain yield and yield variability. Field trials were conducted in three hydrological zones (drought-prone fringe, middle and flood-prone centre positions) of the Kilombero floodplain in 2015, 2016 and 2017. We compared farmers' management (no field leveling and bunding, and no mineral or organic amendments) with different “good agricultural practice” (GAP), which is a set of recommended crop, soil, water and weed management practices including field bunding, land levelling, application of mineral fertilisers or organic amendments, and combinations thereof with no application of herbicide and pesticide. Grain yield and yield variability between positions, years and replications were assessed. Rice grain yields were highly variable, ranging between 2.1 and 11 t ha<sup>-1</sup>. Yields were generally higher in 2015 and 2017 than in 2016, and more so in the drought-prone fringe and the middle than in the flood-prone centre positions. Farmers practice resulted in lowest yield and highest yield variability between years and positions. The simple bunding of the plots and the leveling of the fields increased water retention, particularly in fringe positions, significantly reducing yield variability between years and positions and increasing grain yields by up to 40 % above farmers' practice. While not always being yield effective, organic amendments (here incorporation of Lablab as pre-rice and *Stylosanthes* as post-rice green manure or application of farmyard manure) tended to reduce yield variability and hence farmers' production risk. Mineral fertilisers produced highest grain yields but resulted also in high yield variability. We suggest that a successful adoption of different components of GAP in floodplain wetlands is not only site-specific (bundling and levelling in fringe and middle positions), but also depends on farmers' priorities to either maximize yields (apply mineral fertilisers) or to minimize variation and hence risk (apply organic amendments).

**Keywords:** Farmyard manure, field bunding, floodplain, green manure, mineral fertiliser, urea

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## Enhancing Rice Yield through Good Agricultural Practices in Sub-Saharan Africa

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In sub-Saharan Africa (SSA), rice is an increasingly important crop but with low productivity levels currently. The estimated farm level yield gap is between 1 to 4 t ha<sup>-1</sup> depending on the rice growing condition due to sub-optimal crop management practices. As a measure to enhance rice yields, good agricultural practices (GAP) were tested in farmers' fields in 33 sites in 19 African countries between 2013 to 2015. A set of 3–4 GAP component technologies were identified based on results from yield gap surveys (YGS) and diagnostic surveys, and expert knowledge. The most prominent GAP components tested were land preparation using locally available tools and implements, improved varieties and certified seeds, optimal crop density, optimal and timely application of organic and inorganic fertilisers, and environmental friendly weed management options. In total, 3000 farmers participated in GAP testing. Yields from GAP plots were compared with yields from YGS for a given site to quantify the impact of GAP on yield. Average yields were higher in GAP plots than in YGS in 90 % of the sites. Overall, a yield advantage of 1 t ha<sup>-1</sup> was realised through GAP introduction. The yield increase was highest in rainfed lowland at 1.2 t ha<sup>-1</sup>, followed by rainfed upland and irrigated lowland at 1 and 0.7 t ha<sup>-1</sup>, respectively. Largest yield gains (>100 %) were achieved under rainfed lowland conditions in Benin, Ghana, and Sierra Leone; under upland conditions (>88 %) in Ghana, Madagascar and Benin; under irrigated lowland conditions (>50 %) in Cote d'Ivoire, Uganda and Ghana. Yields were lower with GAP in rainfed conditions in a few sites due to severe drought and/or improper execution of GAP. The results of this Africa-wide study suggest that yield can be improved by large-scale introduction of best-bet and best-fit GAP component technologies in SSA. The farmers who participated in the GAP testing were monitored subsequently to assess the adoption potential of GAP component technologies in all sites. The presence of an enabling environment for easy accessibility and affordability of GAP technologies are important to achieve rice self-sufficiency in Africa.

**Keywords:** Irrigated lowland, rainfed lowland, upland, yield gap

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## Nutrient Balance of Rainfed Highland Rice - Legume Crop Rotation in Northern of Thailand

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Highland farmers in Thailand grow one rice crop per year. However, these farmers lack soil maintenance measures as well as crop rotation. A rice-legume crop rotation could therefore be a way to improve land use in these areas. With the objective to increase overall farm productivity and additional income of farmers, an on-farm study was executed in the Mae Wak village, Mae Chaem district, Chiang Mai province at an altitude of 670 m asl between April 2016 and March 2017. A randomized complete block design was used with five treatments and three replicates. The treatments were: (1) rice (*Oryza sativa*) monoculture, (2) rice - navy bean (*Phaseolus vulgaris*), (3) rice kidney bean (*Phaseolus vulgaris*), (4) lablab (*Lablab purpureus*) rice - navy bean and (5) lablab rice - kidney bean. Fertilisers were applied in rice with 156 kg ha<sup>-1</sup> of urea (46% N) and 156 kg ha<sup>-1</sup> of 16-20-0 (N-P-K) at 25 and 45 days after planting, respectively. Navy bean and kidney bean received 125 kg urea ha<sup>-1</sup> and 125 kg NPK ha<sup>-1</sup> at 25 and 45 days after planting, while no fertiliser as applied in lablab. No pesticides or herbicides were applied. The experiment showed that rice grain yield with 5.5 5.7 t ha<sup>-1</sup> was non-significant different between the treatments. Legume grain yield was 1.5 – 1.6 t ha<sup>-1</sup> in navy bean and 1.0 – 1.3 t ha<sup>-1</sup> in kidney bean. Total crop residue and nitrogen retaining in the soil was significant different between treatments. Total crop residue in rice legume crop rotation increased by 1.4 – 1.6 times compared to rice monoculture. Nitrogen retained in the soil increased by 2.0 – 2.2 times in rice-legume and 2.6 – 2.7 times in lablab-rice-legume when compared to rice monoculture. Nitrogen showed an overall negative balance throughout the experiment with a N removal of 4.6 51.8 kg N ha<sup>-1</sup>, with the highest N removal registered for the rice monoculture treatment. Therefore, a rice - legume based cropping system reduced the nutrient removal from the highland rice fields. Furthermore, future work has to evaluate the adoption of crop rotation by highland farmers and has to explore the local knowledge on sustainable agriculture.

**Keywords:** Legume, nutrient balance, rice

## Multi-Locational Agronomic Evaluation of Four Forage Legumes Adapted to Degraded Soils of the Patía Valley in Cauca, Colombia

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Climate vulnerability is affecting livestock production in the tropics. In addition, poor management practices such as overgrazing, overstocking and deforestation are converting livestock production in one of the main drivers of soil degradation, resulting in expansion of the agriculture frontier looking for fertile lands. An alternative to reverse soil degradation is the use of improved forages (i.e., legumes and grasses) with the ability to grow in degraded soils and recuperate them rapidly.

Aiming at evaluating the agronomic performance of herbaceous forage legumes under the conditions of Patía Valley-Cauca/Colombia, four species were established under dry sub-humid climate and low fertility soils of various stages of degradation. The species tested were: *Canavalia brasiliensis* CIAT 17009, *Centrosema molle* CIAT 15160, *Stylosanthes guianensis* CIAT 11995 and *Desmodium heterocarpon* CIAT 13651. Previous studies have shown a broad adaptation of these species to marginal/stressed environments and the production of high nutritious forage. As control a naturalized forage grass was included (*Dichanthium aristatum*). The field sites were cleared using glyphosate (Roundup 1.5 L ha<sup>-1</sup>) and fertilised with P, K, Mg and S (22, 41.5, 20 and 20 kg ha<sup>-1</sup>). Legumes were sown in 2016 at three locations with different levels of degradation (high to low) Piedra Sentada, Mercaderes and Patía, under the following conditions: average rainfall 1616 mm year<sup>-1</sup> mean temperature 32°C, at an altitude of 800 m asl for Mercaderes and 500 m asl for the two other sites. A complete randomised block design with 3 repetitions was used. Each plot was 100 m<sup>2</sup> with a sowing density per hectare of 25 kg for *C. brasiliensis*, 2 kg for *C. molle*, 3 kg for *S. guianensis* and 1 kg for *D. heterocarpon*. Once established (2017), forage dry matter productivity (DM ton/ha/42 days) was assessed in the wet season. Results showed that *S. guianensis* had the highest productivity at all 3 locations (3.2, 2.2 and 4.8 DM ton/ha/42 Day, respectively) compared to *C. brasiliensis* (2.1, 0.8, 3.9), *D. heterocarpon* (3.0, 2.2, 1.8) and *C. molle* (2.5, 1.6, 2.6 respectively). Productivity during the dry season will be measured to evaluate performance under drought conditions, anticipating a higher drought tolerance of the deep rooted legumes.

**Keywords:** Adaptation, forage legumes, livestock production, soil degradation

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## Performance of *Mucuna pruriens* as a Cover, Feed and Green Manure Crop in Banana-Based Systems in Eastern Democratic Republic of Congo

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Intercropping in banana systems in central Africa is mainly practiced during the rainy seasons, and in low density plantations. Few intercrops are cultivated in more dense plantations and during dry season months. Integration of shade- and/or drought-tolerant crops in these banana systems could significantly boost overall farm biomass production, provide additional forage and a year-round ground cover. *Mucuna pruriens* is a tropical legume widely used as a forage, fallow, soil cover and green manure crop due to its rapid growth rate. The plant also fixes nitrogen thus fertilising the soil. A total dry biomass production ranging from 7-11 tonnes ha<sup>-1</sup> has been reported. *Mucuna* prefers hot, humid climates with annual rainfall of 1,000 - 2,500 mm, but will grow with annual rainfall as low as 400 mm, possibly due to its often deep root system. The crop exhibits reasonable growth under drought and shaded conditions. Integration of this legume in banana fields, during contrasting seasons was assessed in eastern Democratic Republic of Congo which has a bi-modal rainfall pattern. The rainy seasons cover February till May (596 mm) and September till December (709 mm), while annual rainfall totals 1,522 mm. *Mucuna* was planted at the beginning and end of the rainy season, and at one month before the end of the rainy season, enabling plantlets to establish before less favourable dry season months. Field management included minimum tillage before planting and hand weeding during the first three months until the soil is completely covered by the *Mucuna* plants. Plant total above ground biomass was assessed on average at 5.2 months after planting. *Mucuna* planted at the onset of the rainy season and under mono-cropped conditions yielded on average 4.0 tonnes ha<sup>-1</sup> of dry weight biomass per annual growing cycle compared with 2.5 tonnes ha<sup>-1</sup> under banana shade. *Mucuna* planted one month before the end of the rainy season yielded on average 0.6 and 2.1 tonnes ha<sup>-1</sup> under respectively, shaded and mono-cropped conditions. *Mucuna* planted at the very end of the rainy season and under shaded conditions yielded 1.14 and 0.38 tons ha<sup>-1</sup> when planted, respectively, in December and May, the former reflecting a less severe dry season. Under mono-cropped conditions, the yields were higher, 4.12 and 1.43 tons ha<sup>-1</sup>, respectively, when planted in December and May. Although biomass yields were mostly lower for planting dates at end/one month before end of rainy season, year-round biomass production and ground cover during the dry season months was achieved, thus contributing to whole farm productivity, and system integration and health.

**Keywords:** Biomass production, drought-tolerance, shade-tolerance, whole farm productivity

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## Findings of an Upland Rice Farming Study Using a Participatory Mapping Approach in Sarawak (Malaysia)

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Cultivation of rice plays an important role in food security and nutrition in the life of the Eastern Penan, a former hunter-gatherer society in Borneo (Sarawak, Malaysia). The main farming practice is upland rice cultivation by the means of slashing and burning in a shifting cultivation system. However, a shortening of fallow periods, caused by population growth, and the intensive land use led to a decline in the forest ecosystem functionality and soil quality, which in turn affected the rice yield. Therefore, sustainable hill rice production is essential to maintaining natural resources and mid- to long-term food security for the locals. To give recommendations for sustainable hill farming practices, a preliminary study in the Penan village of Long Lamai (Upper Baram watershed) was conducted. With a population of roughly 600 the village relies on rice farming for subsistence. A participatory research approach was chosen, in which local community members were part of the research team. 183 structured interviews and participatory mapping were conducted to assess key variables of hill rice cultivation, including: production methods, soil aspects, rice varieties, yields and weather conditions during cropping. Spatial references were drawn on aerial images and in a later stage digitised with a GIS program.

Results show a median 6-years fallow period and a one-year cropping phase. Generally, fields are intercropped with two or more kinds of crops, i.e. corn, cucumber or tapioca. The yields comes to a mean of  $1.8 \text{ t ha}^{-1}$ . Soil fertility was rated as high/ medium/ low/ degraded with ratios of 28 %, 35 %, 28 %, and 7 % respectively. Overall, fertiliser application is not common in the village, while pesticides are used on 50 % of the examined fields. On average, the farmers used  $3.8 \text{ l ha}^{-1}$  per year of pesticides. The amount applied has steadily increased since 2013. Because of poor weed management, higher use of pesticide weakly correlates with higher yields. With the participatory mapping approach, a first impression was drawn that the applied farming practices is showing a trend of shorter fallow periods and higher external inputs in the village of Long Lamai.

**Keywords:** Food security, participatory mapping, shifting cultivation, upland rice

## Characterizing Lowland Rice-Based Farming Systems to Identify Intensification and Diversification Options in Central Highlands of Madagascar

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Highlands of Madagascar are one of the major rice producing areas, which contributes around 20 % of the national rice production. Apart from rice, the highlands are also suitable of dry season legumes and vegetables production. Despite the large potential to produce more rice and other crops, the reasons for the current low productivity of these lands are unknown. Therefore, it is important to understand the biophysical and social-economic aspects of the current farming systems, and the interaction between rice production and farmers' other farm or off-farm activities, to be able to improve the overall land productivity.

This study aims at investigating the agronomic, economic and social context to be able to characterise rice-based farming systems to identify opportunities for intensification and diversification options for sustainable productivity. The resulting knowledge will be used to support farmers to improve their livelihood through better income from rice related and off-season activities, and climate-resilient rice-based farming systems.

A rapid survey was conducted at 218 representative farm households in 19 villages in the central highlands. The methodology described in Alvarez *et al.* (2014), a cross-sectional retrospective method (consisting of two questionnaires: a screening and a main questionnaire), has been used and multivariate analysis conducted to assess farm characteristics.

The results of (1) farmers characterisation, (2) activities that have had repercussions for their use of rice fields, and also the labour availability and inputs for proper management of the rice fields, (3) major constraints to grow rice and other crops and to maintain the productivity, and (4) the alternatives for dry season cropping to improve the overall land productivity will be presented.

**Keywords:** Diversification, rice, off-season

## A Farming Systems Analysis in Ethiopia's Wheat Belt: Challenges and Perspectives for more Sustainable Agricultural Systems

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Ethiopia is challenged to increase food security, reduce poverty and environmental degradation. About 54 % of the total wheat is produced in Ethiopia's wheat belt, mostly by smallholder farmers (SHF). Increased mono-cropping results in surging weed, wheat rust and insect damages. The aim is to enhance the understanding of SHF-systems in the region and to identify challenges/perspectives for more sustainable agricultural systems.

In total 593 randomly sampled smallholder farms were analysed using descriptive and statistical analysis. A focus group discussion and literature review served to clarify and complement these data.

The results display following averages: farm size 1.7 ha, 6.3 household members, wheat yield 2.27 t ha<sup>-1</sup>, 1.3 t for own use. Most farms are mixed with 90 % of farmers owning one ox or more. An increasing number of oxen positively correlates with increasing yield as it probably allows for timelier field operations. Best yield results are achieved by farmers that (partly) use tractor ploughing. About 60 % of farmers mention insects, wheat rust and other pests and diseases as their main challenge in wheat production followed by a "shortage of inputs" and "lack of rainfall". 74 % apply herbicides and 85 % fungicides/insecticides in wheat. Soil fertility problems was only mentioned by two farmers, though this issue might aggravate in time as soil erosion and insufficient organic matter management due to non-return of dung, stubble grazing, and deficient crop rotation management are widespread. Farmers with regular crop rotation (always changing crop and  $\leq 25$  % of wheat) showed 28 % higher yields compared to farmers with some crop rotation ( $\geq 50$  % of wheat). 38 % of farmers apply regular, 56 % some and 6 % no rotation. In average farmers dedicated 58 % of land to wheat, 15 % to malt barley and 9 % to faba beans. The less land farmers have, the more wheat they grow. Shrinking farm sizes, agronomic and market challenges – among others – for (legume-) crops such as faba bean appear to hinder increased percentages of legumes in the crop rotation. Crop rotations in general indicate negative humus balances, high weed pressure and high risk of soil borne diseases and thus partly explain the relative low yield performance.

**Keywords:** Crop rotations, Ethiopia, farming systems, food security, productivity, sustainability, wheat

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## **Agroeconomic Evaluation of Food Production in Conversion Systems to Organic Farming in Orizona, Goias State, Brazil**

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This study aimed to describe the most important characteristics of two farms who are in conversion from conventional to organic farming in the municipality of Orizona, Goias state, Brazil. A rapid participatory diagnosis was done, to identify the characteristics of interest, which included: (a) the physical, social and intellectual relationship of producers in the development of economic activity; (b) the type of agriculture and livestock in use; (c) the condition of land tenure and use, water availability, and waste management; (d) the use of machinery and equipment on the farm; and (e) improvements in the area, the form of association, media and access to technical assistance and technology transfer. From the results found, it was possible to conclude that: (a) The market for organic products in the region is promising, with an average advantage of 20 % profitability over conventional products. However, consumer awareness is lacking to accept this difference, related to the quality of the product. (b) The creation of an agroecological transition food producers' association to enable the delivery of packaged and certified products to other more consuming markets is still lacking. (c) The main barrier to adopt the research recommendations for these farms was specifically directed to the lack of specialised and qualified technical assistance from the State of Goias to work with the dairy production in the region and lesser difficulty to implement the compost to produce vegetables. (d) The producer expects that the residues generated by livestock farming will be reused rationally in their property for local sustainability, with a greater awareness of the people who deal with and work on the property.

**Keywords:** Agroecology, family farming, technological profile

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## Status and Constraints of Agricultural Diversity Practice in Malawi: Case of Lilongwe District Smallholder Farmers

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Malawi, a country with 70 % of the land allocated to maize production and having maize dominated diets, is engaged in a serious drive towards agricultural diversity. A comprehensive understanding of the current state of agricultural diversity in Malawi was needed since existing studies were limited to either crop, livestock or agroforestry diversity alone. The Crops for Healthy Diets: Linking Agriculture and Nutrition (HealthyLAND) project conducted a study in Lilongwe District of Malawi to document the status of agriculture diversity related farming systems. A survey targeting 424 smallholder households was conducted in 2016 and 2017. Stratified sampling was used to select the farmers from 36 villages of four ecological zones administratively called Extension Planning Areas (EPAs).

Results showed that land holding sizes were small, with a mean of 1.682 acres per household, on which a mean of 2.41 different crops were grown. Farmers identified maize (82.5 %) as their main crop followed by groundnuts (5.4 %) then soy beans (4.7 %). Main cropping patterns were crop rotation (46 % of households), permanent stand (34.7 %) and intercropping (19.6 %). Significantly low proportions of households had backyard gardens at 22.4 %, while 18.4 % practised irrigation and 21.5 % practised conservation agriculture. Agroforestry practice (73.4 % of households) was significantly high but the growing of trees for fruits was low as 40.3 % of households grew mangoes, 2.9 % grew guavas, 3.3 % grew paw paws, 2.4 % grew bananas, 1.9 % grew Mexican apples and lemons. Livestock production was also low since only 50.9 % of households owned chickens, having a mean of 7.97 chickens per owning household; 26.2 % of household owned a mean of 2.8 goats; 17.5 % of the households owned a mean of 3.27 pigs; and only 1.7 % of the households owned a mean of 3.43 cows. The results reflected low agricultural diversity.

Farmers cited low access to seeds and inputs, limited access to land, poor access to markets, poor security, inadequate knowledge for production, and bad weather patterns as reasons why they were not practicing agricultural diversity. Policy makers and stakeholders should support farmers to address the bottlenecks to agricultural diversity so that farmers can have more diversified and therefore resilient farming systems.

**Keywords:** Agricultural diversity, agroforestry, crops, livestock, Malawi

## **Determinants of Adoption of Sustainable Intensification-Enhancing Technologies: Evidence from Cotton-Wheat Zone, Pakistan**

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Increases in agricultural production are often driven by the adoption of technologies including improved quality farming inputs. In low-income countries such as Pakistan, farming household's social and economic conditions greatly determines the adoption of technologies. The study in hand is conducted to examine the role of farming capital variables and socio-demographic including food insecurity of smallholder farming households which assesses the adoption of sustainable intensification (SI) enhancing technologies in Pakistan. We elicit food security outcomes by Household Food Insecurity Access Scale (HFIAS) - an instrument that has not been used in Pakistan for adoption assessment before. We focus the quality of crop care inputs (fungicide, herbicide, insecticide, and seed treatment) as a SI enhancing technologies. The study conducted in cotton-wheat zone of the Punjab, a major contributor in agricultural GDP in Pakistan (N=275 smallholder farming households, multi-stage random sample). Using an ordered probit model, we tested for the influence of farming capital variables and socio-demographic on adoption of improved quality crop care inputs. The finding shows that off-farm income, farm machinery, neighbourhood adopters, education, agricultural extension services, age, cotton area sown, and no-tillage have statistically significant and positive association with the adoption of SI enhancing technologies. Regression estimates also shows that adoption of SI enhancing technologies have negative but statistically significant association with household's food insecurity ( $P < 0.01$ ). Further analysis using endogenous switching regression will seek to reduce endogeneity issues in order to determine if a convincing case for advocating improved quality crop care inputs can be made. For policy implications, based on these results, we suggest to consider that (a) agriculture extension services should more aggressively encourage adoption of improved quality inputs, (b) implement more effective restrictions on sub-quality, uncertified crop care inputs, (c) adoption should be further encouraged through alleviating food insecurity in smallholder farming households.

**Keywords:** Crop care inputs, food insecurity, smallholder farming households, sustainable intensification

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## Investigation of Indigo (*Indigofera tinctoria* L.) and Roselle (*Hibiscus sabdariffa* L.) Intercropping Effect on Weed Density

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Intercropping is one of the most effective methods to achieve a sustainable agriculture system. In order to investigate the effect of intercropping indigo (*Indigofera tinctoria* L.) and roselle (*Hibiscus sabdariffa* L.) on yield and weed biomass, an experiment based on a randomised completely design with three replications, was conducted on the South Kerman Agricultural and Natural Resource Research and Education Center, Iran, in 2014. Treatments were different plant densities of indigo and roselle in an additive and replacement intercropping system: 100:100, 100:50, 50:100, 50:50 and monoculture of indigo and roselle, respectively. The results showed that a maximum yield of roselle (1114 kg ha<sup>-1</sup>) is obtained at the 100:100 intercropping ratio showing a 29.3 % higher yield as compared to roselle in monoculture. The density of the weed Amaranth (*Amarantus* sp.) in the 100:100, 50:100 and 100:50 ratios of indigo and roselle, was 57.4 %, 81.5 % and 70.4 % lower as found in the Roselle mono culture, respectively. Maximum plant density of the weed Cyprus (*Cyperus* sp.) was found in both indigo and roselle mono cultures as well as in the 50:50 intercropping. Plant density of further weeds in 100:100, 100:50, 50:100 and 50:50 ratios were 77.7, 48.2, 51.9 and 44.4 % lower as found in the roselle mono culture. Weed biomass in the 100:100, 50:100 and 100:50 ratios was 25.4, 16.0 and 23.4 % less than in the roselle mono culture and its lowest amount (84 g m<sup>2</sup>) was encountered in the 100:100 system. It seems that the mono cultures and the 50:50 intercropping of indigo and roselle offered the best ecological niche for weed development; all other intercropping ratios seem to repress weed development.

**Keywords:** Indigo, intercropping, roselle, weed density

## Modelling Catchment-Scale Erosion Mitigation Potential of Legume-Led Crop Rotations under Varying Slope Lengths

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The highland regions of western Kenya are domicile to agricultural activities, but simultaneously constitute a major hot-spot for water-driven soil erosion due to erosive rainfall, intensive land cultivation, and steep topography. In the smallholder-dominated Rongo sub-county land tenure is traditionally organised in strips in slope direction and predominant maize plots are ploughed downhill. Slope length and degree have pronounced influence on surface run-off and soil erosion. The question arises, can legume rotation systems placed in strategic landscape positions minimise effects of slope length on soil degradation and nutrient loss emanating from severe run-off? This study applied biophysical field measurements and modelling to answer this question. The study aimed at improving knowledge of the impact of slope length on farmer selected legume-based cropping systems on sustainability of the production base (soil fertility), environment (run-off, soil loss) and food production. We measured run-off and soil loss on bounded plots of: a) 12 × 4 m RCBD under different legume cover (*Mucuna pruriens*, *Lablab purpureus*, *Arachis hypogaea*) planted in pure stand and *Zea mays*/ *Phaseolus vulgaris* intercrop (farmers' practice) with/ without *Calliandra calothyrsus* leaf mulch; b) 20, 60, and 84 m slopes under *Zea mays*/ *Phaseolus vulgaris* intercrop at different locations in the landscape. Experimental data were employed for modelling in a 20 km<sup>2</sup> watershed using the landscape model LUCIA (Land Use Change Impact Assessment). LUCIA was validated with one-year field datasets on run-off and soil loss. Field results showed that *Mucuna pruriens* proved most effective in controlling run-off and soil loss after the *Calliandra* mulch treatment, whereas, highest run-off and soil loss was observed under farmers' practice and *Lablab purpureus*. Larger soil loss was observed on the longer slope lengths. Model scenarios include rotation of cover legumes with maize intercropped with grain legumes, placement of cover legumes in strips at upper and middle slope positions, expansion of legume cultivation area at the landscape-scale to explore the impact of slope length on soil degradation and food security. In-depth stakeholder discussions on model outputs will focus on identification of sustainable conservation measures and implementation pathways.

**Keywords:** Landscape, legume, simulation, slope length, smallholder, soil erosion

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## Analysis of Smallholder Vegetable Production Systems in the Bolivian Highlands

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The small-scale, low-input vegetable production in the Bolivian Highlands under harsh climatic conditions is often not profitable, nevertheless, these small-scale farmers supply the vegetable markets in La Paz and El Alto, two of the biggest markets in Bolivia. Information about these producers are scarce, but needed to provide a solid base for interventions in this sector. This study has the goal to analyse and describe the smallholder vegetable production system in the Altiplano of the department of La Paz, Bolivia. It contains a comparison of the vegetable production on open field and in greenhouses. Furthermore, it offers a general overview of the market and it attempts to show important aspects of climate change and gender.

The methodology is based on a survey with 53 open field and greenhouse vegetable producers, on interviews with experts working with these producers and as well as on key informant interviews.

The vegetable production continues to be manual work, few open field producers use tractors for the field preparation. The use of chemical pesticides and of certified seed is common. The most important vegetable crops produced in greenhouses are oak leave lettuce, butter head lettuce and lambs lettuce. In the open field production crisp head lettuce, onion, broccoli, and cauliflower are the most important crops. The greenhouse vegetable products are delivered to a company, the open field vegetable products are sold to retailers in the markets of La Paz and El Alto. The problems with the market are: fluctuating prices, selling to intermediaries and the stands in the market. The income from crisp head lettuce, broccoli, and cauliflower do not cover the production costs, however, the other three vegetable crops have a positive net income. The differences between the two production systems are important and need to be considered if action in this sector should be initiated.

**Keywords:** Bolivia, greenhouse, open field production, smallholders, vegetable markets

## Options for Sustainable Intensification of Maize Production in Nigeria

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Sub-Saharan Africa (SSA) is the region at greatest food security risk because by 2050 its population would increase 2.5-fold and demand for cereals approximately tripled. SSA's self-sufficiency (a ratio between domestic production and total consumption or demand) in staple cereals is among the lowest compared to other sub-continent, indicating current levels of cereal consumption already depend on substantial imports. To meet the increasing food demands and protecting environmental quality simultaneously, in a sustainable manner, it is necessary to optimise agronomic management practices to enhance the nitrogen and water use efficiency. Various approaches have been proposed to overcome soil nutrient limitations such as i) conventional intensification mainly based on increased use of mineral fertiliser, ii) using legumes in rotation with main the crop or intercropping systems, or iii) a mix of both by rotation with legumes and supplementary mineral N supply. The mixed approach is widely being promoted in agricultural development programs for small-scale farming in SSA, Estimation of resource use efficiency of double-cropping and crop rotation system is scarce, especially in SSA. Therefore, here we use SIMPLACE modelling framework to identify suitable intensification options for maize-based cropping system in three districts of Nigeria, namely Kwara, Edo and Ogun through investigating (i) long-term crop yield response and (ii) change in crop available N over time. The simulations were run at  $10 \times 10$  km grid cells for 29 years (1982–2010) and aggregated to the district level for comparing the effects of intensification options. Results indicate that an increase of 276 %, 199 % and 186 % in maize yield could be achieved in Kwara, Edo and Ogun respectively under the intensification option where maize was grown in rotation with groundnut and  $60 \text{ kg N ha}^{-1}$  was also applied when compared to the yield levels achieved under conventional farming practices (i.e., under current mineral fertiliser application rate).

**Keywords:** Food security, intensification, maize, Nigeria

## Appropriate Agricultural Mechanisation for Increased Crop Productivity and Income Generation in Rural Ethiopia

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The growth of available farm power per hectare has been very slow resulting in high drudgery on smallholder farms of Ethiopia. Low horse power (8–20 hp) two-wheel tractors (2WT) offer an option for rural farmers in addition to animal traction and human muscle based systems that characterise smallholder agriculture in Ethiopia. The 2WTs are multi-purpose, offering services such as direct planting with precise seed and fertiliser placement, harvesting, threshing and shelling, water pumping for irrigating high value crops, and transport. Smallholder farmers can have access to these tractors and equipment through services provided by individual and youth group service providers (SPs). Smallholder farmers benefit from the services provided by SPs while the SPs can generate income for themselves in the process of providing services in rural communities. CIMMYT and its partners have been testing and promoting the use of 2WT based technologies including planters for maize, wheat and teff; threshers for wheat, teff and other related crops; maize shellers; reaper harvester for wheat, water pumping for irrigation of high value crops and trailers for transportation. The cost benefit and profitability analyses were conducted for each 2WT accessory separately and in combination to gauge the economic viability of single and combined operations from both the farmer's and service providers' stand point. The gross margins per ha when farmers use 2WT based technology is higher by 55–89 % compared to a non-mechanised farmer practice. The higher gross margins were due to reduced costs for ploughing, planting, fertiliser application, threshing and transportation for both crops. Service provision of 2WT based technologies proved to be viable and profitable generating a high and positive Net Present Values (NPV). A combination of seeder, thresher, trailer and water pump gives the highest financial benefit ranging from US\$24,465 to US\$62,081. With initial capital investment cost of US\$7,275 the second more profitable combination is the seeder, thresher and trailer that can generate US\$24,122–US\$61,738. Break-even point in hours of machinery operations for the seeder, transport and thresher is 27.3–304.3 hours. Therefore, agricultural mechanisation has a high potential of reducing drudgery on farms, increasing farm productivity and generating income in rural Ethiopia

**Keywords:** Drudgery, Ethiopia, food security, income generation, mechanisation, service provision, smallholders, two wheel tractor, youth employment

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## Agronomic Evaluation of a Collection of *Cenchrus ciliaris* under Tropical Dry Forest Conditions

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Cattle farming is one of the main agricultural activities in Colombia and the main source of income for many farmers. In order to make the cattle sector more productive and resilient to, there exists a need to explore new forage options responding to adverse and changing climates in the warm regions of the country and more general in the Latin American tropics.

With the aim to evaluate the agronomic adaptation and response of a collection of *Cenchrus ciliaris* during the establishment phase and production, plots of 9 m<sup>2</sup> were planted under a randomized complete block design, with four replications, and using for control commercial materials previously evaluated in the region (e.g. *B. brizantha* cv. Toledo). The research was carried out in the Patía Municipality of the Cauca Department, an inter-Andean valley located in the south of Colombia at an altitude of 608 m asl, characterised by tropical dry forests with soils of medium fertility and long dry periods.

Once the collection of 20 accessions was established, the agronomic evaluation was started using the methodology of the International Network for the Evaluation of Tropical Pastures (RIEPT), which takes into account variables such as vigor, coverage, height, incidence of pests and diseases, flowering, green forage and dry matter production.

The evaluations were carried out in two years during periods of maximum and minimum precipitation, which allowed to observe the performance of the materials and to pre-select the following ones according to the dry matter production when compared with the best control materials: *B. brizantha* cv. Toledo had a yield of 43.3 t ha<sup>-1</sup> year<sup>-1</sup>; *B. hybrid* cv. Cayman 40.31, and *Panicum maximum* cv. Mombasa 31.98, respectively. The genotypes evaluated with best yields were the accessions 6642, 15687 and 13299, with an average production of 39.59, 37.33 and 36.50 t ha<sup>-1</sup> year<sup>-1</sup>, respectively. These results show that, despite of having a lower forage production than the control materials of *Brachiaria* and *Panicum*, the evaluated materials can be an excellent alternative for the potential adaptation to the evaluated agro ecological conditions.

**Keywords:** Forage production, germplasm

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## Biological Efficiency (BE) of *Pleurotus ostreatus* on Corn Straw and Supplemented Sawdust in Pelotas - Brazil

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In recent years, mushrooms production (*Pleurotus* spp) has increased around the world due its degrading capacity, versatility and low complexity at cultivation process. The South of Brazil allows the development of this activity once presents satisfactory climatic conditions: mild temperature and high humidity and a wide availability of subsistence agriculture residues. In this experiment was used: 70 % of corn straw, 15 % of eucalyptus sawdust, 8 % of wheat bran, 5 % of gypsum and 2 % of calcium carbonate to pH 5.5 and 2 % of *P. ostreatus* var. Florida inoculum in relation to the wet weight of used substrate. The substrate preparation was conducted by immersing the ground of corn straw in water for 24 hours, after this period occurred the mixture including the sawdust, wheat bran and supplements. This mixture was conditioned in 5 kg bags. In sequence bags were submitted to the vapour chamber at 95°C for 8 hours. The cultivation took place in a rubble greenhouse with controlled humidity. A total of 22 bags were observed, as result, the production volume of week 1 and 2 were similar ( $p = 0.154$ ), the same occurred at week 2 and 3 ( $p = 0.092$ ). The production volume of week 3 was lower when compared to week 4 ( $p = 0.015$ ). The mean values to mushroom's production per bag was 1025,45g. The mean values of week production per bag were: 361g ( $\pm 118$ ) to week 1, 297g ( $\pm 80$ ) to week 2 and 226g ( $\pm 86$ ) and 154g ( $\pm 20$ ) respectively to week 3 and 4. The result of BE=68.4 % indicates satisfactory result for the first contact between fungus and substrate. The present productive process is a sustainable option to study region considering the availability of corn straw and eucalyptus sawdust, another research is investigating the effectivity of this process on farm system.

**Keywords:** Biological efficiency, mushrooms, South of Brazil

# Abiotic and biotic challenges in crop production

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## Invited Paper

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## Adaptation Study at Altitudinal Gradients Hints Plant Response to Climate Stressors

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Increasing global food demand due to population growth and rising of living standard of both rural and urban population in one hand and decreasing global food production due to urbanisation, degradation of cultivable land and climate change on the other are threatening future food security. Changes in two weather parameters, temperature rise and erratic rainfall, are introducing multiple biotic and abiotic stresses at different sensitive growth stages in most of the locally adapted and farmer preferred crops resulting in low productivity. In 2008, GIZ/BMZ funded RISOCAS project addressing Adaptation of African Agriculture to Climate Change aimed to investigate response of temperature and other weather parameters on crop growth and development. We conducted trials along three altitudinal and temperature gradients (Andranomanelatra, 1625 m asl; Ivory, 965 m asl and Ankepaka, 25 m asl) in Madagascar using 10 upland rice genotypes for two consecutive years (2008 and 2009) to examine responses of temperature on upland rice. Daily mean air temperature during upland rice growing season was 7 – 22°C in the high altitude, 19 – 27°C in the mid altitude and 17 – 29°C in the low altitude. The relationship between mean air temperature and crop parameters showed that unit increment in air temperature decreased crop duration by 5 to 9 days and increased crop yield by 0.1 to 0.3 t ha<sup>-1</sup> depending upon genotypes, indicating that rise in air temperature is favourable for upland rice cultivation at high altitudes, and expansion of upland rice growing area in high altitude regions (hills, mountains, highlands) can contribute to global food security to certain limit.

**Keywords:** Crop duration, thermal gradient, upland rice, yield components

## Exploring Potentials for Narrowing Farmers' Wheat Yield Gaps in Golestan Province, Iran

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Yield gap describes the difference between the potential yield of a specific crop genotype in a given environment and farmers' actual yield. Narrowing yield gaps offers the opportunity to increase production without expanding cropland. Quantifying and explaining farmers' yield gaps allows identifying the constraints that farmers face regarding productivity and evaluate opportunities to narrow yield gaps. Golestan province in northeastern Iran is an important national base for wheat production and contributor to food security. Here we collected primary production data of 540 wheat producing farm households, which we selected through a stratified random sampling procedure. Building on farmers' reported crop management as well as site-specific soil information and daily weather data, we employed the AquaCrop model to estimate each individual farmer's water limited and potential wheat yields under current and optimised management. With average actual yields of 3.5 t ha<sup>-1</sup> and potential non-water limited yields of 8.2 t ha<sup>-1</sup>, we identified a wheat yield gap of nearly 60 %. By solely optimising irrigation management, yield gaps could be reduced from 60 % to around 50 %. If farmers could overcome all other yield limitations including weeds, pest and diseases as well as suboptimal timing of management measures, yield gaps could even be reduced to around 20 % using current (suboptimal) irrigation practices. The analysis shows that the often-claimed necessity and potential of improving irrigation water supply and management is only one (relatively small) part of the solution. To narrow yield gaps in Iranian wheat production it requires a broader approach that integrates stable input supply and training of farmers in all aspects of crop management.

**Keywords:** AquaCrop, farm survey, wheat, yield gap

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## Comparison of Multi-Locational Phenological Responses of Rice Cultivars to Altitudinal Gradients in Temperature

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The increasing demand for land suitable to secure human food security in the future has already impelled agricultural production into marginal lands. In these, environmental conditions have a much more pronounced impact on agricultural productivity. In addition to that, climate change is expected to increase the unreliability of weather conditions for farmers considerably, thus endangering food security in developing countries in particular. Rice, as an example, is a staple crop and main source of carbohydrate for large parts of humanity, has been adapted to a wide range of environmental conditions, and offers a great possibility to fill in future gaps in food security. Nevertheless, in many regions, such as the Highland of East Africa, the choice of varieties adapted to these specific environmental conditions is limited, often not tested yet.

In order to test the impact of temperature due to altitudinal gradients on the phenological development of rice varieties in East Africa, field trials have been set up. One field site is located in northern Ethiopia, two sites in southern and western Rwanda and two sited in central Madagascar. The sites were selected to represent altitudinal gradients, with overlapping elevations to enable cross-country comparisons. Planting dates were distributed throughout three calendar years, with continuous iterative planting dates taking place in Madagascar, in- and off-season planting dates in Rwanda with different fertiliser regimes, and one planting date during each rainy season in Ethiopia testing different management options. Out of a wider selection of varieties, we have selected 4 rice varieties (Chhomrong, IR64, X-Jigna, Yun-Keng) grown under a total of 9 different thermal environments to compare and evaluate the phenological performance such as days to emergence, days to panicle initiation, days to heading/booting, days to flowering, days to maturity.

These results will help to identify a) potentially suitable varieties for further adaptation to East African Highland environments, b) help to improve phenology-dependent fertiliser recommendation and c) offer the potential to adapt existing or devise new cropping calendars, suitable for the security of future food production systems.

**Keywords:** Altitude, East Africa, phenology, rice, temperature

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## **Agroecology as a Pathway to Build up Sustainable Food Systems - Experiences from the Semiarid Regions in Brazil, India and Senegal**

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Agroecology has much to offer to the more than 500 million smallholders worldwide. Despite the socio-economic and environmental challenges that smallholder farmers face, they play a unique role and pose immense potential for constructing more sustainable food systems. Increasingly, elements of stewardship, mitigation, approaches embracing sociocultural diversity and biodiversity, and sustainable and dignified livelihoods are all coming together under the heading of agroecology.

To assess the potential of agroecology for smallholders in semi-arid regions, the co-operation agency MISEREOR conducted three country studies together with local NGOs from Brazil (Centro Sabiá), India (SSP) and Senegal (Enda Pronat). The studies compared farmers adopting agroecological practices with a control group (non-adopters). Per country, about 200 agroecological farmers and 200 farmers from the control group were interviewed. The main field phase of the first study started in India in April 2016, the second study followed in July in Brazil and the third study was conducted in March 2017 in Senegal. After the field phase, the data was analysed and the preliminary results were discussed at country workshops with farmers on site.

The studies provided consistent information that farmers working under agroecological approaches are performing considerably better than their peers. In all countries, agroecological farmers produced more food than the control group and had an increased yearly income. Such production also reflects on food security, as the first group presented better results for food self-consumption and a more diverse diet (percentage of increase in the value for self-consumption in comparison to control group: Brazil: 100 %, India: 67 %, Senegal: 14 %). Therefore, the families need to buy less food on the market and are less vulnerable to volatile food prices. Also, earnings from selling agricultural produce increased considerably: in Brazil 177 %, India 79 % and Senegal: 36 %. The poorest households benefitted most from increased incomes.

In sum it is possible to sustain that agroecological systems have a promising potential in rural development and are ‘pro-poor’, particularly if oriented to vulnerable populations living in regions susceptible to climate change impacts.

**Keywords:** Agroecology, climate change, resilience, rural development

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## Screening of Provitamin A Maize Inbred Lines for Drought Tolerance Using Morpho-Physiological and Biochemical Traits

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The potential role of maize (*Zea mays* L.) in combating food insecurity in sub-Saharan Africa (SSA) is indisputable given the wide production and consumption in this region. However, its role in curbing nutrition insecurity is questionable due to lack of key micronutrients such as vitamin A. This has been deemed to be contributory to high prevalence of ‘hidden hunger’ related conditions such as vitamin A deficiency (VAD) in this region. On the other hand, maize production in this region is constantly under threat from recurrent and episodic droughts. Development of drought tolerant biofortified maize could be a solution to food and nutrition insecurity in this region. Drought tolerance being a complex trait requires integrated approaches of selecting candidate genotypes. In this study, with the objective of selecting drought tolerant candidate inbred lines, 46 provitamin A maize inbred lines and 4 drought tolerant checks were screened under optimum and drought conditions in the greenhouse and field for drought tolerance using grain yield, anthesis silking interval (ASI), number of ears per plant (EPP), plant height, stomatal conductance, leaf senescence, chlorophyll content, leaf rolling and proline content. Analysis of variance, Pearson’s correlation coefficient, principal component analysis and drought tolerant index were computed. There were significant differences ( $p \leq 0.001, 0.01, 0.05$ ) among the genotypes’ performances under both optimum and drought conditions. Some inbred lines that had high grain yield under both optimum and drought conditions scored moderately high to high values for yield components such as number of ears per plant, kernel weight and shelling percentage under drought conditions. Moderately high to high proline content was observed and was positively correlated to grain yield under drought stress. Under drought, the first two principal components were most influential contributing 59.22% of the total variation in which ASI and EPP had higher loadings followed by proline content and grain yield. Seven lines were earmarked as drought tolerant with twenty-four lines being moderately drought tolerant. These results suggest that proline content might be considered as one of the biochemical traits that can be used in screening maize for drought tolerance.

**Keywords:** Biofortification, drought, inbred line, maize, provitamin A

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## Nitrogen Distribution Analysis for All Seeds of Cowpea (*Vigna unguiculata*) Using Single-Seed near Infrared Spectroscopy

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Cowpea is an important crop for food security, as it is a primary source of protein and cash income for farmers in the dry savannah areas of sub-Saharan Africa. Improved varieties should contain reasonable amounts of protein in the grains, and to ensure this, timely and cost-effective analytical methods are strongly required. Recently, a procedure for estimating the cowpea grain nitrogen (protein) content in single seed using near infrared (NIR) spectroscopy was developed. The technique was able to estimate nitrogen content in intact seed within 20 sec. It was expected that the developed technique would be able to evaluate the protein content in new varieties and/or for nutritional screening in cowpea breeding program. However, nitrogen distribution in a plant is still poorly understood. In this study, evaluation of nitrogen content with all seeds in one plant was performed using single seed NIR technique. A total of 4,005 seeds were collected from five plants (Tvu456) according to location information, such as a peduncle position node, number, and position of seed in the pod. Then, nitrogen content of each seed was evaluated. Average seed number was  $801 \pm 487.1$ , maximum seed number was 1600 and minimum seed number was 373 per plant. Average nitrogen content was  $3.79 \pm 0.53$  %N, and maximum and minimum N% were 6.52 and 3.42 per seed, respectively. Nitrogen content had positive correlation with seed weight and the seed weight varied widely (average:  $112.6 \text{ mg} \pm 88.5$ ). However, it was thought that there was no particular relation between N content and node position or seed position in the pod. These relationships will be discussed in the presentation.

**Keywords:** Cowpea, near infrared spectroscopy, nitrogen content, protein content, single-seed measurement

## Genetic Diversity and Population Structure of Red Pericarp Rice from Madagascar and Togo Using SSR Markers

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Red pericarp on rice (*Oryza* spp) is one of the traits which interests breeders and farmers in Madagascar. However, there are no genetic diversity studies done on this specific rice in Madagascar. Research reporting of traditional varieties are a source of variation. Understanding the genetic diversity in the available genotypes is very important for the crop improvement. The objectives of this study are to assess the genetic diversity and relationship of rice accessions from Madagascar and AfricaRice genebank, and to build a core collection of these accessions for conservation and for starting point of a breeding program.

20 SSR markers were used to characterise 238 genotypes from FOFIFA (National Center for Applied Research and Rural Development), AfricaRice genebank and also from farmers preferred varieties.

A total of 192 alleles were detected among the 238 genotypes. The number of alleles varied from 4 (RM21) to 20 (RM11 and RM164) with an average of 11.29 per locus. The mean PIC value per locus was 0.64 with a maximum value of 0.81 recorded for SSR marker RM 001 and lowest value of 0.15 observed for SSR marker RM215. Heterozygosity varied from 0.01 (RM168 and RM 256) to 0.27 (RM205 and RM222) with an average of 0.12. The principal coordinate plot showed two distinct clusters, African rice genotypes grouped in cluster I and Madagascar genotypes in cluster II, and the cluster II subdivided into three subgroups A, B, C. The analysis of the molecular variance (AMOVA) revealed that 38 % of the variation was attributed by difference among individuals, 47 % among population and 15 % of variation was associated with individuals. 61 genotypes were assembled to present the core collection, 17 are African genotypes. Genotypes from Madagascar are very diverse, however those from AfricaRice can be source of private alleles.

**Keywords:** Genebank, genetic diversity, *Oryza* spp, red pericarp, traditional variety

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## Effects of Day and Night Temperature on Rice Photosynthesis

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It has been shown that the yield of rice (*Oryza sativa*) decreases in response to higher night temperatures. Projected temperature increases due to climate change are expected to be more pronounced at night. As the primary staple for more than half of the world's population, a decrease in rice yield could pose a serious threat to food security. However, the physiological response of rice to night temperature is not yet fully understood. Studies indicate both positive and negative effects of high night temperatures on CO<sub>2</sub> assimilation and growth in rice. It has also been shown that the physiology of rice during the day is also affected, as warmer nights lead to higher leaf conductance and net assimilation rates during the day. It is unclear if the day response is part of a mechanism to compensate for depleted carbohydrate pools within the leaves from night-time respiratory CO<sub>2</sub> losses. A day-time increase in net assimilation, comprised of assimilation, day respiration, and photorespiration, implies changes in the photosynthetic complex to either reduce CO<sub>2</sub> releasing processes or an increase in assimilation.

In the presented study, groups of 5-week-old IR64 rice plants were exposed to six different two-week long day and night temperature treatments in a growth chamber. After one week of adjustment to the temperature treatment, photosynthetic parameters, such as assimilation rate, stomatal and mesophyll conductance, and respiration and growth parameters, such as leaf area, biomass, tiller number were measured among sampled plants. During the temperature treatment, the youngest developed leaf on the main tiller was shaded for 40 hours, and on re-exposure to light assimilation was measured. In both temperature and shade treatments, leaf samples were taken to determine levels of non-structural carbohydrates and active Rubisco content.

**Keywords:** Climate change, mesophyllic conductance, night temperature, photosynthesis, photorespiration, respiration, rice



## On-Farm Rice Diversity and Farmers' Preferences to Varietal Attributes in Ayeyarwady Delta, Myanmar

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Crop genetic resources are the corner stone of sustainable agricultural development as these can be used to improve crop varieties adaptable to heterogeneous environmental conditions. Myanmar is one of the centres of genetic diversity of rice and there are still many landraces present in the country. Moreover, the diversity of *Oryza sativa* in Myanmar is the highest in Southeast Asia. The main objectives of this survey were to identify the current varietal diversity of monsoon season rice in Ayeyarwaddy delta, the rice bowl of Myanmar, and to assess farmers' preferences for rice varietal traits. A total of 150 respondents were randomly selected from five townships, namely, Bogale, Mawlamyinegyun, Labutta, Myaung Mya, and Pathein, in Ayeyarwaddy region. The survey questionnaires included data on rice varieties grown, major problems in rice production and associated socio-economic characteristics. Farmers' preferences on rice varietal traits were measured by using 24 important traits, which were scored from 1 (extremely important) to 3 (not important). Almost 83 percent of the sampled farmers cultivated more than one variety per season. Growing several varieties per season serves as a function of risk management and for resilience to diverse weather conditions. Varietal diversity was higher in areas affected by salinity and there was no correlation between farm size and levels of varietal diversity. The diversity on-farm was high since 39 different rice varieties were found. Among those 39, farmers mostly grew Pawsan varieties, Mee Shay, Ayeyarmin, Manaw, and Madama, as top five varieties. Fifty two percent of total cultivated land in sampled villages was occupied by Pawsan group, therefore, those Pawsan varieties are of high importance in the Ayeyarwady delta. The farmers ranked the varietal attributes according to their preferences in the following order: i) high market demand, ii) high yield with less inputs, iii) resistance to insects/diseases, iv) high milling recovery, and v) less broken rice. Understanding farmers' preferences would also increase variety diversification.

**Keywords:** Farmers' preferences, Myanmar, rice, varietal diversity

## Assessing Seed Germination and Seedling Vigour in Rice under Different Thermal Regimes

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Rice production environments are quite diverse and often cropping calendar options are limited by either water availability or low temperature. Sustainable intensification of rice production systems requires flexibility in the choice of cultivar, sowing date, and management options. In transplanted systems, nurseries provide options to exploit early genotype  $\times$  environment to the advantage of later development stages. In order to target nursery management to specific systems changes, it is important to know germination and early seedling vigour capacity of genotypes potentially subjected to new growing environments. Therefore, germination capacity, mobilisation efficiency of grain reserves, days to onset of photo-autotrophy and partitioning of early dry matter gains to the different organs was investigated under temperature regimes typical for tropical low altitude (28/20°C day/night) and tropical high altitude systems (20/12°C day/night) for four contrasting irrigated lowland rice genotypes. Rice was grown in wet loamy sand in a climate chamber and was destructively sampled for plant organs and remaining kernel weight for 14 days after seedling emergence in two day intervals.

Germination and early seedling vigour differed significantly among the genotypes and the temperature regimes. Results indicate that low temperatures extend the period of initial water uptake during germination. Once hydrated, seeds metabolic activities followed the same patterns as under optimal temperature. In cold tolerant varieties mobilisation of grain reserves during early growth of the seedling resulted in smaller respiration losses than in cold sensitive genotypes and thus a higher mobilisation efficiency. In contrast, cold sensitive genotypes reached photo-autotrophy earlier but took longer to compensate respirational losses during germination, resulting in a reduced early seedling vigour. The implication for nursery planning and varietal selection for flexibility in cropping calendars will be discussed for rice growing areas at high altitudes in East Africa.

**Keywords:** Cold stress, germination efficiency, *Oryza sativa*, management option, reserve mobilisation efficiency

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## **Quantifying Impacts of Raising Seawater Levels and Resulting Saline Water Intrusion on Sustainability of Paddy Production: A Vietnamese Case**

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Increasing soil salinity is an environmental stressor, which causes significant reduction in cultivated land area, crop productivity and increase in risk of farming. Salt-water intrusion in the dry season is a major concern in Vietnam due to geographical and meteorological conditions. In particular, in the north central coastal region of the country, soil salinisation is considered to be one of the most serious problems affecting rice and other crops, limiting crop productivity and affecting food security. To better understand the adverse impacts of soil salinisation in crops from the north central coastal region of Vietnam, this study investigates production risk under salt water intrusion in rice producing areas taking the cases in four communes of Thua Thien hue province using J-P stochastic production function. Electrical Conductivity (EC - a term used to describe a measurement unit of salinity) was measured in order to examine the salinity level in both dry and wet crop seasons of surveyed farms. The model of relationship between EC and rice yield is presented to determine how much rice yield is changing by salinisation impact. The regression result shows salinity is clearly impacting yield levels resulting in an average yield loss of  $0.164 \text{ Mg ha}^{-1}$  per unit of EC increase. Simultaneously, results from the risk function show that higher EC levels increase the variance of yield. Possible options to offset the impacts of climate changed induced salinity are discussed in the context of rice production and regional food security. This study can be used to help derive site-specific yield goals in context information on EC correlations with rice yield and yield variability is limited.

**Keywords:** Climate change, impact assessment, rice, salinity, South East Asia

## Transplanting Instead of Direct Seeding as an Option to Mitigate Abiotic Stress Conditions in Rainfed Lowland Rice in High Altitude Rice Systems of Ethiopia

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Rain fed lowland rice in the high-altitude plains of Ethiopia is constrained by two major abiotic stresses (1) available precipitation during the cropping period and (2) low temperatures causing spikelet sterility towards the end of the cropping season. Current practice of direct seeding is constrained by water availability as fields are sown after the first rains which may be delayed or less intense than optimal. The productivity of rice is additionally restricted as only short to medium duration varieties can be grown due to the risk of spikelet sterility during flowering which coincides with the cold stress. The system could gain flexibility by changing from direct seeding to transplanting. For transplanting, rice is sown in seedbeds, which require much less space and water and thus allow for more variability in the sowing date. Depending on the seedbed duration, a share of the basic vegetative phase (BVP) is already happening before transplanting, which may offer an opportunity to also include long duration varieties by increasing seedbed time and transplanting older seedlings that may still reach flowering during optimal temperature conditions. Seedbed duration can also act as a buffer period in case the onset of the rainy season is delayed. A field study was conducted in the 2016 and 2017 cropping seasons with the aim of investigating variation the effect of the crop establishment methods on the phenological development and yield performance of contrasting rice genotypes. Ten genotypes contrasting in duration (110 to 175 days), were simultaneously direct dry seeded and transplanted as three weeks old seedling at the Fogera National Rice Research and Training Center research station. The experiments were carried out in randomised complete block design with three replications. Data on phenological development, yield, and yield components was recorded and analysed. Differences in the rate of phenological development as well as yield performance were clearly observed between transplanting and direct seeding. The results of this study will provide information for the design of new or adapted crop calendars and crop management recommendations, thus helping to improve and stabilise yields of rain fed lowland rice farming systems.

**Keywords:** Cold stress, direct seeding, genotypes, phenology, transplanting, yield

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## Development of a PVS2 Droplet Vitrification Method for Yacon (*Smallanthus sonchifolius*) Cryopreservation

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Yacon [*Smallanthus sonchifolius* (Poepp. and Endl.) Robinson] is a perennial root crop belonging to the *Asteraceae* family and originating from the Andean region. It is cultivated for its edible tuberous roots high in inulin-type fructooligosaccharides of low caloric value. This study aims at developing an efficient cryopreservation protocol for long-term preservation of yacon using the PVS2 droplet vitrification method, which is considered to be an emerging generic method for cryopreservation of plant tissues. Until now, no studies have been reported of this method being applied to this species. To carry out the experiment, 1.8–2.5 mm apical shoot tips were excised from 3–4 weeks old *in vitro* cultures of an octoploid yacon landrace, originated from Ecuador and maintained at Czech University of Life Sciences Prague. Excised shoot tips were exposed to loading solution and three different time intervals for PVS2 dehydration at 0°C were tested. Shoot tips were then exposed to ultra-rapid cooling on aluminum foil strips (0.5 × 2 cm) in liquid nitrogen (LN) and were then rewarmed in 1.2 M sucrose MS (Murashige and Skoog, 1962) liquid medium. Post-cryo cultures were placed on recovery MS media containing 6-Benzylaminopurine (BA) and on MS without BA to determine which media was more efficient for survival and recovery after PVS2 droplet method. Ten shoot tips per treatment were used and 3 repetitions were carried out to ensure the reliability of the results. Callus formation, shoot plus callus formation, full growth normal, hyperhydration and colour of shoot tips were evaluated. Preliminary results showed that yacon can survive after cryopreservation using PVS2 droplet vitrification. Survival of shoot tips exposed to short time (15 min) PVS2 was higher; the optimal recovery media was MS without BA as BA induced a higher level of hyperhydration and callus formation in post-cryo cultures. However, further evaluation will be carried out on post-cryo cultures to ensure the regeneration of well-rooted plants that can survive *ex vitro* transfer. Cryopreservation of crop species contributes to the world food security. The long-term conservation of this species is important, as it ensures the safe storage of the species for future generations.

This research was financially supported by the Internal Grant Agency of Faculty of Tropical AgriSciences, Czech University of Life Sciences Prague IGA (Project No. 20185015) and the project QJ1630301 of the Czech Ministry of Agriculture. BP gratefully acknowledges the Directorate-General for Development, Belgium (DGD) for their financial support to the project 'Safeguarding vegetatively-propagated crop diversity to nourish people now and in the future'.

**Keywords:** Long-term preservation, PVS2, *Smallanthus sonchifolius*

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## Salinity Tolerance of Guava (*Psidium guajava* L.) and the Implications for its Adaptation into Saline Environments

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Water scarcity and salinity increasingly aggravate agricultural production. Natural boundaries imposed by soil salinity also limit the caloric and nutritional potential of agricultural production. Therefore, it is important to determine the salt-tolerance threshold of crops and to identify well-adapted genotypes. Common guava (*Psidium guajava* L.) is highly valued for its delicious fruits, which are an excellent source of vitamins, minerals, and natural antioxidants. However, guava production is faced with salinity challenges in many guava-producing countries, such as Brazil, Mexico, Australia, India, Sudan, and Kenya. In a six-week greenhouse experiment, guava plants were subjected to salinity levels of 0 mM (control), 10 mM (low), 20 mM (medium), and 40 mM (high) of sodium chloride (NaCl) to test the level of salt tolerance. The leaf dry biomass decreased with increasing salinity by 7.8, 26, and 67 percent in the low-, medium-, and high-salinity levels, respectively, while the same remained constant in the stems and roots. Consequently, the shoot/root ratio decreased with increasing salinity, suggesting that the root was less sensitive to salt stress than the shoots. An analysis of the proline levels confirmed the effect of salt stress on the leaves as proline increased with higher salinity. In accordance, the sugar content (fructose and sucrose) of the leaves also raised with increasing salinity, ranging from 0.98 g/100 g in the control to 1.67 g/100 g in the 40 mM treatment. The net photosynthesis in the salt treatments decreased in comparison to the control. Guava was not efficient at excluding Na from the transpiration stream as high amounts of Na were accumulated in leaves with increasing salinity until at 40 mM NaCl, when the plants began to die. This suggests that guava can tolerate a salinity concentration of less than 40 mM which should be considered for selecting guava accessions for adaptation to saline environments.

**Keywords:** Adaptation, NaCl, proline, *Psidium guajava*, salinity tolerance, selection, sugars

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## Morphological and Physiological Responses of Seagrape (*Coccoloba uvifera* L.) Seedlings of Different Provenances to Salt Stress

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Seagrape (*Coccoloba uvifera*) is a small tree widely distributed along the Atlantic, Caribbean and Pacific coasts of the American tropics and subtropics. It is an important tree for edible fruits, ornamental plantings and coastal windbreaks. Although its tolerance to salt stress was reported, physiological information on the salt tolerance mechanisms at seedling state is not available. The effect of salt stress on some morphological and ecophysiological traits of seagrape seedlings of different provenances was evaluated under greenhouse conditions. Plants were subjected to different salt levels by adding NaCl (Control, 5, 15, and 25 dS m<sup>-1</sup> NaCl) during four weeks. The morphological (shoot height, root length, root and shoot weight and root/shoot ratio) and physiological (leaf water content, root water content, chlorophyll fluorescence, specific leaf area and leaf area) traits were evaluated. The salt stress levels had negative effects on morphological traits of seagrape seedlings, whereas the seedlings showed different responses on salt stress in dependence of their provenance. At the highest level of salt stress the seagrape seedlings did not survive. Shoot height and root length were reduced up to 38 % and 27 %, respectively, at 5 dS m<sup>-1</sup> and up to 72 % and 73 %, respectively, at 15 dS m<sup>-1</sup>. The reduction of dry weight was between 43 % at 5 dS m<sup>-1</sup> and 74 % at 15 dS m<sup>-1</sup>. Salt stress also reduced the water content in roots and shoots. This salt stress test with seagrape seedlings can be an effective approach to screen salt tolerance of seagrape genotypes. However, it is necessary to carry out more studies with seed of other provenances and *in situ* experiments to obtain further information about salt tolerance of seagrape.

**Keywords:** *Coccoloba uvifera*, provenances, salt stress, tolerance

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## Canopy Dynamics of two Climate-Smart Cassava Varieties under Drought in SW Nigeria

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Cassava (*Manihot esculenta*) is a major staple in Nigeria and elsewhere in sub-Saharan Africa where it is grown without irrigation. However, the estimated yield gaps between those obtained on farmers' fields (12 Mg ha<sup>-1</sup>) and on research stations (up to 60 Mg ha) remain high. There is also little information about yield determinants and the impacts of the dry season on growth, leaf area development, senescence, and biomass partitioning of the cassava plant and how these impacts vary between variety and with fertiliser application. Given projected changes in rainfall, we conducted a study to understand better the development of the crop as well as the growth response to water deficiency during the dry season. This was part of the "African Cassava Agronomy Initiative" sponsored by the Bill & Melinda Gates Foundation. The factorial experiment compared the responses of two drought-tolerant varieties of cassava (TMEB 419, IITA-TMS-IBA980581), to four different potassium fertiliser treatments (nil fertiliser, 75 kg N ha<sup>-1</sup> and 20 kg P ha<sup>-1</sup> with 90, 135 or 180 kg K ha<sup>-1</sup> elemental application rates) and two different planting dates, replicated in four blocks and at two sites in South West Nigeria. Measurements over the dry season (October 2017 – February 2018) included biomass partitioning, light intensity and canopy interception with the aid of a ceptometer, leaf senescence and leaf area estimates. Preliminary observations show TMEB 419 with a taller stem and less dense canopy than IITA-TMS-IBA980581. Relationships between dry season response and yield in 2018 will be established allowing to optimise the planting time and fertiliser regime for each variety.

**Keywords:** Cassava, climate-smart agriculture, manioc, sub-Saharan Africa, sustainable intensification

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## **Analysis of Yield Components and Photosynthetic Limitations of a Dwarf Rice Variety in Response to Shade**

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Tree intercropping is said to be a promising approach to replenish poor soils, mitigate drought events and prevent erosion. However, cereals like rice, wheat and maize that comprise the major calorie sources for the world's population, show large reductions in yield when intercropped within trees. This fact is often attributed to tree-crop competition for nutrients, soil moisture and light, where the latter is a resource solely limited by environmental conditions that cannot be replenished.

While crop adaption strategies to shade regarding the adjustment of yield components and the biochemical properties of the photosynthetic complex are relatively well described, there is a lack of consensus about how far the different diffusional resistances to CO<sub>2</sub> (stomatal and mesophyll) are adjusted in shade. We therefore combined a yield component analysis of rice plants grown in a climate chamber experiment under 2 different levels of shade (50 and 75 percent compared to a control treatment) and an analysis of diffusional and non-diffusional (biochemical) limitations to flag leaf photosynthesis.

Grain yield of shaded plants was reduced by 80 and 100 % for plants grown under 50 and 75 % shade, respectively. The yield component analysis revealed that the total number of tillers was the main factor causing yield reduction for plants grown under 50 % shade (58 % contribution to grain yield loss) while the ratio of productive tillers remained almost constant between the treatments. Furthermore, average kernel weight contributed 19 % of the reduction in yield, followed by kernel number per panicle (10 %) and percentage of filled spikelets (9 %). For plants grown under 75 % shade, all yield components contributed equally to total yield loss (20 % each).

A photosynthetic limitation analysis showed that in all treatments leaf mesophyll conductance of CO<sub>2</sub> was the largest contributor to limitations in photosynthetic capacity. However, plants grown under 50 % shade consistently showed the highest photosynthetic capacity and a significant increased mesophyll conductance compared to plants grown under full light or 75 % shade during the whole vegetative phase.

Additional results will be shown and a short illustration of the methodology will be given.

**Keywords:** Mesophyll conductance, rice, shade, yield components

# Crop biotic stresses (DPG Session)

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## Evaluation of Control Options to Reduce the Impact of the Fall Armyworm, *Spodoptera frugiperda*, on Maize in Smallholder Cultivation on the “Plaine de La Ruzizi”, DR Congo

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The “plaine de la Ruzizi” at the border of DR Congo, Rwanda and Burundi is a fertile arable land where cassava and maize present(ed) the principle food crops. As the cassava brown streak disease that destroyed the entire root harvest essentially eliminated cassava production in the region, maize gained considerable ground as the main staple food. The arrival of the fall armyworm, *Spodoptera frugiperda*, a disastrous pest of maize, at the beginning of 2017 resulted in an enormous devastation of the crop and caused severe food shortages. More seriously, because of the lack of any knowledge about the pest and options for its control, the resource poor farming community was left rather helpless in the combat to reduce the impact from the calamity that was foreseen for the coming cropping season. Our intervention, to assist the community in controlling the pest considered, accessible methods and locally available materials, the use of a biological insecticide (Conserve) based on *Saccharopolyspora spinosa* compounds and the use of a synthetic insecticide. The latter was in particular significant because the farmer community demanded for any product that could provide immediate relief. Our experimentation considered the best moment to begin the control action by scouting fields for signs of insect eggs, nymphs and frass windows, efficacy of control, and repetition of treatment. Four variables were compared on demonstrations plots at 3 sites and on maize parcels of 10.5 m × 48 m. Reducing the numbers of insects by crushing egg masses, nymphs and collecting caterpillars and the application of a home-made wood ash/oil mix were compared with chemical treatments using Conserve (Dow Chemical) and the most generally used Rokat (40 % (Profenofos) + 4 % (Cypermethrin). Because there was complete absence of any concept on safe use of pesticides, demonstration and training was provided on precautionary measures, the use of protective overalls and gear as well as safety of users and passers-by.

We report the results, experiences and knowledge gained from two seasons of interventions to combat the fall armyworm attacking maize in the South Kivu region and discuss the options left for small resource poor farmers to reduce the severe impact of this pest and to assure food on the table.

**Keywords:** DR Congo, fall armyworm, maize

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## Evaluation of Hermetic Technologies in Controlling Insect-Pests, Mould Infestation and Aflatoxin Contamination of Stored Maize

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Hermetic storage technologies, as a food-insecurity intervention, create a bio-generated atmosphere that offers a safe and reliable storage solution for maize grains. There are many studies about their effectiveness against post-harvest pests in SSA but little information exists on their effectiveness against mould and mycotoxin infestation. Furthermore, previous studies have not compared the performance of hermetic technologies with the conventional synthetic pesticides and their effectiveness against both mould proliferation and insect infestation. Trials simulating African smallholder farmer conditions were conducted in the postharvest laboratory at Kiboko (a semi-arid area in Kenya) and at University of Nairobi laboratory for 8 months during the 2017 storage season. There were eight hermetic treatments (metal and plastic silo, and 6 brands of hermetic bags) against two non-hermetic treatments (a registered synthetic pesticide and untreated control, in polypropylene bags). Maize grains were subjected to two levels of moisture (12–13 % and 14–15 %) and two levels of natural and artificial fungal inoculation (*Fusarium* and *Aspergillus*). Treatments were arranged in a RCBD. The study found that hermetic treatments were significantly superior to non-hermetic treatments in the prevention of mycotoxin, and fungal development among other benefits. However, there were no significant differences between metal silos and hermetic bags regardless of the mode of infestation. The aflatoxin levels were not significantly different in the dry inoculated grain, across all the storage technologies ( $p = 0.05$ ) compared with the baseline levels. This indicates that, within 8 months of storage, mould proliferation is not likely in dry grain stored under hermetic conditions. However, in the inoculated grains with high moisture, there was an increase in aflatoxin levels in both hermetic and in the control by 5.7 ppb and 12.1 ppb, respectively. At high levels of moisture, the grain is likely to be contaminated by the mycotoxins in both hermetic and conventional storage technologies. There was a strong correlation between total insect and fungal population per kg which indicate the importance of controlling insect pest during storage to reduce losses. Also, fungal population and mycotoxin levels increased exponentially with moisture increase in the non-inoculated grains. *Aspergillus* and *Fumonisin* spp. were higher in the controls compared with the hermetic storage technologies hence low oxygen reduced fungal proliferation.

**Keywords:** Food insecurity, fungal inoculation, hermetic storage, mycotoxins, post-harvest insects

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## Control of the African Cassava Brown Streak Disease with Virus Resistant Cassava Germplasm from South America

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Cassava brown streak disease (CBSD) is the most devastating disease of cassava (*Manihot esculenta* Crantz) in East Africa and is presenting a serious threat to cassava cultivation on the continent. The two virus species, Cassava brown streak virus (CBSV) and Uganda Cassava brown streak virus (UCBSV) cause a very similar disease but differ in their ability to replicate in cassava. On the plant side, there are cultivars that respond with severe symptoms particularly on roots while others respond to CBSD viruses with mild symptoms on leaves and stems only, have unblemished roots and maintain a low virus titer. Nevertheless, all African cassava cultivars become virus infected and there is uncertainty whether those resistant lines are resistant against UCBSV, CBSV or both viruses.

Virus screening to identify resistance in cassava under field conditions is very critical and often doubtful because it is bound to the presence of virus(es) and their infection pressure. Virus type, vector behaviour and inoculation time contribute to uncertainty in finding the right sources. The aim of this study was to develop an efficient laboratory method for virus screening of cassava and to screen the diversity of South-American cassava germplasm (maintained in the CIAT germplasm repository) for resistance against CBSVs. For screening large numbers of cassava plants, we had to develop a robust and efficient virus inoculation and evaluation workflow.

Our search for natural resistance in 238 South-American cassava lines revealed that most South-American cassava varieties tested were susceptible to CBSV. However, we also identified 9 cassava lines that did not become infected while in further 9 lines, CBSV was not found in leaves but the virus was restricted to the root tubers. The resistance was characterised by further biological assays with cassava, also including other virus isolates and molecular experiments to quantify and localise virus in the infected susceptible and the resistant immune cassava plant. Preliminary results from field trials show the outstanding CBSD resistance of South-American cassava varieties. This work provides convincing evidence for the invaluable contribution of germplasm collections to supply the genetic resources for the improvement of our crops.

**Keywords:** Cassava, cassava brown streak disease, resistant immune plant, virus screening

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## Practices and Perceptions of Pesticide Use in Tropical Wetlands: An Assessment from the Nyabarongo Lower Catchment in Kigali, Rwanda

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The use of pesticides in tropical wetlands is important to ensure the availability of vegetables throughout the year. This is particular the case for the valley bottom wetlands in high altitudes, overpopulated countries such as Rwanda, where this is strongly promoted by the government. However, the potential negative effects allied to farmer's perception, which influence pesticides handling and use are often neglected in policy making due to nearly non-existing research on the topic. This study aimed in-filied identification of pesticides used; how they are used, unhealthy behaviour associated with pesticide in order to inform decision makers. A multi-level data collection which included deep interviews with district agronomists (n=20), smallholder farmers (n=40) covering vegetables farming plots (n= 165) was conducted during July and August 2016 and 2017, and October to November 2017. The study revealed that majority of farmers poorly uses insecticides and fungicides. 73 % of respondent reported a complete lack of pesticides education; this is reflected in unhealthy behaviours that include pesticides mixing and the wash of empty containers and equipment with wetland water (80 %). Furthermore, even though the application rates were always lower than rates recommended on labels, the intensity of application was two to three times higher than the recommended intensity. The high frequent use was influenced by factors such as weather variability, habitual behaviour such as saving field from upcoming pests rather than following indications on labels, farm size or intended crops. The results call for urgent integration of farmer's education in the pesticides policies, followed by regular evaluation of farmer's perception toward pesticides. This study contributed to monitoring pesticide residues in water and soil as a part of a broader PhD research project on anthropogenic disturbances and effects of agrochemicals on environmental quality in major wetlands of Rwanda.

**Keywords:** Farmers perceptions, pesticide use, pesticides, wetland

## **Implementation of IPM-Programme for Clean and Safe Rice in Mekong River Delta (Vietnam)**

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Considering the current level of extensive international food trade, food safety has become a significant global issue. Hundreds of pesticides, including herbicides, insecticides and fungicides are among the most hazardous chemical compounds extensively applied in agriculture to increase food production. These are intended to destroy and control pests, weeds or plant diseases. Pesticide application is strictly regulated to protect consumers and the environment.

Ensuring food safety and further promoting agricultural exports are issues that Vietnam has in recent years been concerned about, seen the following facts: Vietnam is a traditional agricultural country and well-known export country for many agricultural commodities such as rice, pepper, coffee, and cashew as well as seafood; in recent years many of Vietnam's agricultural products have not crossed the trade barriers of USA, EU and Japan due to food safety and pesticides residues. So Vietnam must change its current agricultural practices and focus on ecological agriculture, but firstly in the next 5–10 years Vietnam has to reduce the amount of chemical fertilisers and pesticides as well as to implement different agricultural policies.

In 2016, the Ministry of Agricultural and Rural Development launched a programme 'Green connection towards a clean agriculture' to strengthen the linkages between various players in the agricultural production chain to improve the competitiveness of and add value to farm produce, enabling them to enter the international market. In addition, the following measurements are necessary: Reduction of overuse of fertiliser, pesticide and herbicide; Reform the land law and lift the farmland limits to push up land accumulation and pave the way for large-scale production; Establishment of co-operative (voluntary participation of small farmers). The Government on February 2 issued Decree No. 15/2018/ND-CP replacing Decree No. 38/2012/ND-CP guiding the implementation of the Law on Food Safety.

In this paper the author will report the results of 2-year implementation of IPM programme in six provinces of Mekong River Delta as well as integrate this important problem in training at university.

**Keywords:** Food safety, IPM programme, pesticide residues



## Comparison of Neem Soil and Foliar Treatments for Controlling the Whiteflies *Aleyrodes proletella* and *Trialeurodes vaporariorum*

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The control of insect pests has largely relied on regular application of synthetic pesticides. However, the development of resistance against major classes of chemicals, pest resurgence, environmental damage and adverse effect to non-target organisms pose a great challenge. Owing to the demand for insecticide residual free food and better ecological approaches to pest control, there is increasing interest in the use of biopesticides such as Neem. This compound has been shown to affect many important pests of different crops; a systemic feeding deterrent, repellent and growth-regulating properties. The potential for their use in the control of crop pest peculiarly whiteflies in organic farming system warrant investigation. Most of the registered products in the market are formulated for foliar application. Despite their high efficacy when in direct contact with the target organism, the oil-based foliar formulations rapidly degrade under high temperatures and UV light. Soil application and uptake of active ingredients by the root systems could avoid this negative effects hence attain higher level of pest control sustainably. The aim of this study, therefore, was to evaluate the efficacy and persistence/ residual effect of neem compounds, applied to the soil either as water based solution or as granules compared to spray application in the control of *Aleyrodes proletella* L. and *Trialeurodes vaporariorum* West. This was done using a foliar spray formulation NeemAzal-T/S (1 % Azal) and two soil applied formulations; NeemAzal-T (1 % Azal) and NeemAzal granules, (7 % Azal). The treatments were done 0, 3, 5, 7, and 14 days before the plants were exposed to adult whiteflies. All basic experiments were conducted in a greenhouse. Larval and pupal mortalities of the whiteflies were analysed using binomial generalised linear models. From our results, neem extracts were effective against whitefly immature stages although efficacy of foliar formulation significantly decreased with time probably because of photodegradation under high temperature. On the other hand, soil-applied formulations attained fast efficacy and long persistence which could indicate fast uptake and systemic translocation of active ingredients but reduced photo-degradation. Therefore, soil application of neem gave the most intensive control and was more persistent than foliar formulation.

**Keywords:** Formulations, neem, whiteflies

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## Morphological and Molecular Characterisation of European Species of the *Diaporthe/Phomopsis* Complex Associated with Soybean Seed Decay

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The genus *Phomopsis* (teleomorph *Diaporthe*) comprises phytopathologically relevant fungi which cause diseases on a wide range of economically important crops including soybean. This group of pathogens has been reported to be involved in several soybean diseases, including *Phomopsis* seed decay (PSD) (*Phomopsis longicolla*), stem blight (*D. phaseolorum* var. *sojae*) and stem canker (*D. phaseolorum* var. *caulivora* and *D. phaseolorum* var. *meridionalis*), resulting in significant yield and quality losses. Accurate species identification of DPC is critical in understanding disease epidemiology and for developing effective control measures. Also, it has been documented that MAT primers are useful in mating-type diagnosis in a wide range of *Diaporthe* and *Phomopsis* species. In this study, we focused on morphological (colour and shape of colonies, existence of alpha, or beta conidia, or both, and their characteristics, production of perithecia, and size of conidia) and molecular analyses of species from DPC-damaged European soybean seeds obtained from several locations throughout Austria, France, and Germany. In addition, the European DPC isolates were classified according to their mating-type loci using Primers MAT1–1-1 FW/RV and MAT1–2-1 FW/RV. Surface sterilized soybean seeds were placed on APDA and incubated for 30 d at 24°C. Putative isolates of the DPC were purified using the single spore method. Genomic DNA was extracted from mycelium of each single-spore isolate. Thirty-two strains of *Diaporthe* and *Phomopsis* were isolated and phylogenetic relationships were determined using the translation elongation factor 1-alpha (TEF1) and nuclear ribosomal DNA internal transcribed spacers (ITS) sequences. By combining morphological and molecular data, four species including *Phomopsis longicolla*, *Phomopsis* sp., *Diaporthe caulivora* and *Diaporthe eres* could be distinguished on soybean seeds. Also, results from mating-type experiments revealed that MAT primers used in this study allowed mating-type diagnosis of the 28 isolates. Further studies for controlling these pathogens using biological control agents are currently in progress.

**Keywords:** *Diaporthe/Phomopsis* species complex, morphological and molecular identification, soybean seed decay

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## Fungal Flora Associated with Canker and Dieback Disease in *Adansonia digitata* and *Sclerrocarya birrea* under Domestication in Eastern Kenya

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Domestication of indigenous fruit trees in drylands agroforestry systems has been threatened by canker and dieback diseases. However magnitude, distribution and identity of associated pathogens have not been documented in Kenya on *Adansonia digitata* and *Sclerrocarya birrea*. About 360 samples were collected from five farms spread over two Agro-ecological zones (Kitui and Kibwezi). 21 fungal species were identified using morphological characteristics and molecular data of the ITS region. Members of Botryosphaeriaceae comprised of 47 % of total isolates and *Lasiodiplodia theobromae*, *Lasiodiplodia mahajangana*, *Lasiodiplodia* sp, *Lasiodiplodia pseudotheobromae* were the most frequent species encountered. Members of Pestalotiopsis species were made up of 30 % of total isolates with Pestalotiopsis sp, and Neopestalotiopsis protearum occurring predominantly. Phylogenetic analysis and closest matches in GenBank showed that the fungal species associated with the fruit trees also occurred in other plant species. Hence plurivorous nature of these pathogens threatens trees and crops in agroforestry systems. The occurrence of main canker and dieback pathogen were significantly correlating with disease in dry season ( $< 0.01$ , Pearson corr. =0.72) indicating the hot conditions favouring their growth. However, occurrence of *Alternaria* was higher in humid areas and during wet season. This study will provide a comprehensive study on fungal flora associated with *A. digitata* and *S. birrea* in eastern Kenya which clearly document the need for detail study of host-pathogen dynamics. It also demonstrate the ability of this indigenous fruit trees to share pathogens with other crops and possibly act as source of reservoir or inoculum for agricultural crops which could compromise disease management strategies on farms. This study will contribute towards epidemiological and management strategies for fungal pathogens in arid and semi-arid lands.

**Keywords:** *Adansonia digitata*, agroforestry, Botryosphaeriaceae, canker and dieback, fungal flora, pestalotiopsis, *Sclerrocarya birrea*

## Resistance Evaluation of Black Bean Germplasm to the Fusarium Wilt Disease

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The common bean (*Phaseolus vulgaris* L.) plays a pivotal economic and social role in Brazil, serving currently as the main source of dietary protein. People's preferences for colour and culinary traits of beans greatly vary among regions, but in the South consumers prefer locally produced black beans. However, several diseases can dramatically reduce the yield potential of this crop, and consequently, have an impact on food security in this region. On the other hand, this scenario offers a big challenge for breeding programs searching for resistant cultivars with high yield without losing focus on local market demands. Fusarium wilt (Fw), caused by the soil-borne fungus *Fusarium oxysporum* f. sp. *phaseoli* (Fop), is one of the most important diseases of bean plants and the use of resistance has been considered the main strategy to disease control. Considering that finding new resistance sources is essential for forthcoming breeding programs, this screening work aimed to evaluate the reaction of 17 black bean genotypes to Fop. The tested genotypes were the lines AL9021332, CF22, CF128, CHP97-04, CI96712V, CP9310635, FT84113, FT991159, LP97-04, MD841, TB9401, UFSC-01, and UFSC-02; cv. IPR88 Uirapuru; and the landraces Becker Bela Vista, Negro Bola, and Sogro Daniel. The assays were carried out under outdoor conditions during spring from August to December 2012 and 2013. Bean plants were grown in 20-L plastic pots containing a substrate composed of Fop-infested clay soil ( $1.3 \times 10^3$  colony forming units g<sup>-1</sup> of soil) and organic compost (3:1; v/v). Fw incidence was assessed at intervals of 4 days (between pod filling until grain filling growth stage) to monitor the incidence of wilt and dead plants during the season. The lines AL9021332, CF128, CP9310635, TB9401 and UFSC-01, and the landrace Becker Bela Vista did not show any Fw symptoms and were classified as resistant. The remaining genotypes exhibited varying levels of disease incidence of 12 to 88 % and were considered susceptible. Finding resistance genes against Fop in local germplasm is possible and makes feasible future breeding programs.

**Keywords:** Fusarium wilt, genetic resistance, landraces, *Phaseolus vulgaris*

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## Citrus Greening Disease, East African Situation: Incidence, Severity and Patterns of Distribution

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Citrus fruits are highly ranked as important crop for household consumption and as cash crop with great economic potential. However, due to attack by pest and diseases, the annual production of citrus fruits in East Africa has been below demand with smallholders producing around 4-10 t ha<sup>-1</sup>, far below the expected 50-75 t ha<sup>-1</sup>. This has resulted to high local requirement with 5 - 21% of the citrus currently supplemented by imports from South Africa and Egypt.

*Trioza erythrae* vector transmits the bacteria *Candidatus Liberibacter africanus* (CLaf) causing African citrus greening disease (CGD) that is a major threat to citrus production in East Africa and beyond. Furthermore, the recent establishment of a close relative vector '*Diaphorina citri*' and the potential of *T. erythrae* to transmit *Candidatus Liberibacter asiaticus* in East Africa (unpublished report), indicates that the two citrus greening vectors and pathogens could be quickly spreading and adapting to new environments that were not reported in the past. The study objective was to assess incidence, severity and distribution patterns of CGD in Kenya and Tanzania and to characterise potential circulating pathogens through sequencing and phylogenetic analyses of 16SrDNA and rplJ genes.

Incidence and severity of CGD varied considerably across the different altitudinal gradients in the surveyed regions ( $P < 0.05$ ). Though CGD was absent in some regions, the disease had widely spread in most of the highlands and midland regions. Lemon had the highest severity with a mean visual score of 2.05. When compared with members of the genus *Liberibacter*, sequence obtained from symptomatic citrus samples linked to CLaf. subsp. *clausena* (KX770998) and CLaf. (GU120044) with the given accession numbers in the gene Bank. The occurrence of CLaf. subsp. *clausena* previously reported on indigenous rutaceous plants and now on citrus plants suggests that they could act as alternative sources of CLaf infection to citrus orchards. These findings help to understand the possible economic and environmental impact other liberibacter subspecies may have on citrus crops and provides valuable insights into understanding and controlling CGD by putting in place stringent phytosanitary measures and internal quarantine system to avoid the spread of the disease to new areas.

**Keywords:** *Candidatus Liberibacter africanus* (CLaf), *Trioza erythrae*

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## Effects of Different *Trichoderma harzianum* Strains on Growth and Production of Secondary Metabolites in *Trigonella foenum-graecum*

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Trigonellin is one of the most potent antidiabetic so far extracted from plant sources. Influence of two *Trichoderma harzianum* isolates (chit4215MK and T8-7MK) on trigonellin production and growth factors of two *Trigonella foenum-graecum* ecotypes (Hamedan and Bandarabbas) were investigated under greenhouse conditions. The results showed that the two ecotypes are different in terms of growth factors. So, Hamadan ecotype showed longer stem length and Bandarabbas ecotype showed higher number of lateral branches and pod numbers. It was observed that *Trichoderma* strains have different effects on the growth of Hamadan ecotypes stem and T8-7MK strain was better than chit4215MK. However, no shoot length differences were observed between the control and *Trichoderma* treated plants for the Bandarabbas ecotype. The data revealed that, there was no significant difference between ecotypes, treatments and the interaction effects of treatment and ecotypes for peroxidase activity and total soluble carbohydrate content. A significantly higher content of trigonellin ( $4 \text{ mg g}^{-1} \text{ DW}$ ) was achieved in T8-7MK *Trichoderma* strain treated Bandarabbas ecotype that was 1.6-fold higher than the control plants. Interestingly, a significantly higher content of trigonellin ( $3.5 \text{ mg g}^{-1} \text{ DW}$ ) was obtained in chit4215MK *Trichoderma* strain treated Hamedan ecotype that was 1.3- fold higher than the control plants. The content of trigonellin in treated Bandarabbas ecotype was higher than the treated Hamedan ecotype (1.3 times more). It was showed that treatment with *Trichoderma* can be able to regulate trigonellin biosynthes and different strains have different effects on different fenugreek ecotypes.

**Keywords:** Fenugreek, growth, secondary metabolites, *Trichoderma harzianum*

# Ethnobotany, resource use and biodiversity conservation

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## Food, Spices and Medicines from Ghana, at the Beginning of European Colonisation and Today

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The Gold Coast was first discovered by the Portuguese Pedro de Santarém and Pedro Escobar in 1471. Two years earlier, in 1469, the trade in the Gulf of Guinea had been leased to a wealthy Lisbon trader by king Afonso V, under the obligation to navigate further south to Sierra Leone, in order to spread both the Christian faith and increase the empire. The paper proposed for this conference starts with the examination of two 16th century manuscripts, by Damião de Góis (1567) and Garcia de Resende, where the first African palm trees, such as *Elaeis guineensis*, and spices like *Amomum melegueta* were mentioned. The methodology proposed also included a survey of flora consumption in Accra, Ghana, formerly known as the Gold Coast, independent from Britain in 1957. The cross-examination of the cultivated and traded species will determine the results, aimed to compare the useful flora and their uses during European expansion and in contemporaneity. Results prove that the African spice mentioned in the manuscripts was replaced by *Capsicum annuum* and *C. chinense*, but palm fruits are still smashed and consumed in stews; the seed is used to make oil and the flower is burned to smoke away undesirable mosquitoes. These insects can transmit such diseases as malaria, against which poor people drink boiled leaves of pawpaw (*Carica papaya*) and *Moringa citrifolia*, to ease fever. A total of 101 plant species were recorded in 2018, mostly used as food. The hope is to contribute to a better understanding of the evolution of flora consumption in Africa, initiated by this scientific mission of the University of Lisbon to Ghana.

**Keywords:** Africa, flora, food, Ghana, malaria, medicines, spices

## Knowledge, Use Diversity and Prioritisation of 46 Multipurpose Species for Conservation in Ouémé Catchment in Bénin

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The search for plants with high nutritional, medicinal and/or commercial potential has been intensified to find candidate species that could help in maintaining a balance between agricultural output and population growth. The Ouémé catchment abounds an important diversity of 46 plant species. Due to their nutritional and socio-economic values to rural households, these useful species are preserved and maintained in farms and are made available in shortage times. However, to date, Ouémé catchment experiments increasing degradation of its natural resources caused by anthropogenic pressures. Consequently, most of the species as well as the cultural and endogenous knowledge related to them are facing a very high risk of extinction. Despite this fact, few published studies concerning their conservation have been undertaken. In this regard, our study focused on (i) assessment of impact of socio-demographic factors and climatic zones on knowledge and use of the 46 species; (ii) assessment of the use status of each of these species (iii) ranking these species according to their priority for conservation using a conservation priority index and (iv) inventory local conservation policies and actions to face their degradation. A total of 411 randomly selected informants were interviewed through a semi-structured survey followed by a field survey in 69 random plots of 0.15 ha. Data from available literature were used to complete the surveys. Ecological and ethnobotanical parameters were computed and the highest priority species for conservation were identified. The results showed significant difference in plant use between women and men, ethnic groups and climatic zones. The findings also revealed that more than 50 % of native species in the study area are underutilised. Six species were classified as priorities: *Parkia biglobosa*, *Pterocarpus erinaceus*, *Milicia excelsa*, *Prosopis africana*, *Azizelia africana* and *Khaya senegalensis*. The conservation approaches most used by local people were: seedlings protection in farms, reduction of harvesting of sensible organ, plant nursery and pricking out in field, conservation of seeds in garret or jar, practice of apiculture favouring pollination. Non-governmental organisations, governments and agroforestry research institutions are entreated to incorporate these species in local development strategies aiming at sustainable management and long term conservation.

**Keywords:** Benin, conservation priorities, knowledge and use, local people, Ouémé catchment, useful plants

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## **Incidence of Pollinators Decline on the International Trade: Social Welfare and Food Security Analysis**

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In the 2014 Rome declaration on nutrition, countries together reinforced their common understanding on food security connectivity to nutritious food consumption. In fact, countries have spent far too long looking solely at calories as the answer to food security; though, if we look at the factors that genuinely contribute to addressing malnutrition and stunting, it is not just calories production alone, but also the production of diverse non-staple foodstuffs. Indeed, ecological and agronomic scientists have alerted the links between the nutritional content of non-staple crops and their full or partial dependence on insect pollination services for their natural process of production. The insect pollination, in general, accounts around 60 % of the world production volume of crops and 35 % of world crop species. The contribution of this service to the value of the world agricultural sector is evaluated between 153 and 260 billion euros representing about 9.5 % of the value of the world edible crops production. Moreover, pollinator dependent crops contribute up to 40 % of the world's supply of nutrients.

Unfortunately, pollinators' population and density are declining globally, while the demand of crops that are dependent on pollinators has been steadily increasing since 1960. In parallel, international trade of agricultural commodities increases which can be seen as one of the ways society adapt to this decline effects.

We propose to consider international trade mechanism into the economic evaluation of pollinators decline impacts on both crops productivity and their nutrients content. For that we simulate precisely changes that may occur in market prices, supply and demand of crops and thus track the variation in nutrients intake due to the new crop market equilibrium if pollination services declines. To specifically 1) quantify variations in the social welfare and thus 2) quantify the variation in the provision of nutrients embedded. Our main findings showed that progressive loss in pollinators' density induces continuous increase in relative marginal cost and market prices, consequently decreases social profit. Moreover, heterogeneity of pollinator loss and dependence by sub-regions might create dynamic comparative advantage for countries.

**Keywords:** Economic evaluation, ecosystem services, international trade, pollination

## **Certification Programs and their Role in Small-Scale Farmers Livelihoods: Case of Rainforest and Café Practices**

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Standards have recently been advocated as tools to aid in consumer protection, improving small-scale producers' competitiveness and sustainable production. Consumers demand for safe products led to the growth of certification schemes in European markets and other markets in the East. For small-scale producers in developing countries, the potential of certification standards to improve productivity, offer better prices through improved market access and better incomes hence food security provides a basis for their adoption. However, the adoption of certification standards has been slow in Africa. Further, evidence of their impact on the livelihoods of small scale producers remains scarce and inconclusive in Africa.

The study sampled a total of 250 small-scale coffee farmers in Kenya. Distributed amongst certified Café Practices, non-Café farmers, certified Rainforest alliance (RFA) and non-Rainforest Alliance farmers. Purposive selection of households was used to control spillover effects and PSM was used to control selection bias. Results show that farmers who participated in Café certification received significantly higher prices per kilogram of coffee than non-Café farmers. However, due to lower land allocation and low productivity, they had lower coffee income per unit acre than non-Café farmers. Additionally, Café certified households received lower total agricultural income despite having a high percentage of households depending on agricultural income for sustenance. Further results show that households participating in RFA received significant lower value of income per unit acre than the non-RFA households. Evidence of negative impact of RFA certification on amount of coffee produced and the total agricultural income of the households was observed. Though not significant, RFA certification increased the price of coffee per kilogram received by certified households. Of importance is that, both certifications resulted in farmers achieving lower productivity than the country's average productivity. Further, over 90 percent of the certified farmers surveyed could not identify the type of certification they held.

This study recommends the need for co-operatives to look past certification, put in place ways to improve productivity of farmers and offer better farmers training programs on the process of certification.

**Keywords:** Certification programs, Kenya, livelihoods, PSM, standards

## High-Resolution Mapping of the Trade in Tropical Commodities: Estimating Impacts of Corporate Zero-Deforestation Commitments

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The production and trade of agricultural commodities in the tropics is both an important source of income (with exports worth around \$270 billion in 2013), and a leading cause of environmental degradation – for example, four commodities (beef, soybeans, oil palm and wood products) are responsible for around 40 % of deforestation in the region. The length and complexity of international supply chains, however, make these impacts all but invisible to the companies and consumers, consuming those products in importing countries. In this presentation, we will outline methods and results from the Trase initiative (Transparency for Sustainable Economies; <http://trase.earth/>), a flagship effort to map international supply chains of tropical commodities, from sub-national regions of production through to the markets of consumption, via the companies handling that trade. We will explain the diversity of datasets required to piece together international trade flows, link actors (e.g. individual companies) to the places where they operate, and estimate the impacts of that trade. Using examples from the Latin American soybean sector, we will explain how Trase can shed light on the efficacy of Zero Deforestation Commitments (i.e. commitments made by companies or countries to ensure that deforestation does not occur in their supply chains). We will discuss variability in the strength of Zero Deforestation Commitments, quantify the growth in their market share, reveal the variability in their geographic coverage, and present some of the first analyses of their net effects (accounting for potential leakage), ultimately outlining the potential for meeting their stated goal of ending commodity-associated deforestation by 2020.

**Keywords:** Accountability, deforestation, soy, supply chain transparency, tropical commodities

## **Ethnobotanical Study of Medicinal Plants Used for Making Herbal Teas in Coastal Syria**

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The area located between Mesopotamia and Mediterranean is an ancient and rich region in folk medicine knowledge which has been accumulated since thousands of years. However, there is a lack of studies to document this knowledge. Our study was carried out in the northwestern part of Syria bordering the Mediterranean Sea with 193 km including coastal plains and mountains. The study focused on ethnobotanical documentation of medicinal plants used in the form of a tea. We aimed as well to analyse a significant part of the local beverage culture by determining uses of herbal teas for both medicinal and recreational purposes. In the period from December 2017 to February 2018, 42 informants from 32 villages were interviewed. In total, 49 medicinal plant species were reported to be used in the form of an infusion tea, of which, three species were not mentioned before in any botanical publication throughout the Middle East. We received 303 use reports, which were categorised into 13 ailment categories. Although most of the plants investigated were used separately, 26 herbal tea mixtures were documented. The data were analysed through calculation of the species use value, informant agreement ratio, frequency of citation, and the cultural value index. Through this last index we could choose the most important local species which could indicate the species with promising economic value. The study contributed to documenting the diversity of medicinal plant species used as an infusion tea, in particular, we highlighted seven important plant species which are strongly recommended for future pharmacological and economical studies.

**Keywords:** Ethnobotany, herbal mixtures, infusion folk medicine

## Ethnobotanical Study of Medicinal Plants Used in Papantla, Veracruz

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Ethnomedicine is still used as primary health care resource by several indigenous communities and people who live in rural areas. In Mexico, most of the indigenous population live in rural areas (61.1 % in communities with less than 2,500 inhabitants). The aim of this study was to record, analyse and identify the medical plant knowledge of the Totonaca ethnic group in Totonacapan region in the state of Veracruz, Mexico. The Totonacos descendants are keen consumers and have a historical background with traditional medicinal uses and are well-known for preserving a wide variety of plants. In the present study, semi-structured interviews were performed with 85 informants aged between 18–85 years old (53 % male and 47 % female). Ethnomedicinal indexes were applied to analyse the collected data. A total of 102 medicinal plant species belonging to 94 genera and 52 families were documented. The families Asteraceae (111 UR) and Rutaceae (99 UR) have the highest number of species with eight plants each one and were the best-represented families in the study area. The highest informant consensus factor (ICF) was calculated for the autoimmune diseases (ICF=0.91) with a unique ailment of cancer. The highest number of use report (N=251) was determined for the diseases of the digestive and gastrointestinal system. The most culturally important species was *Hamelia patens* Jacq., obtaining the highest importance cultural index (CI) with 0.906 (77 UR), it presented the widest spectrum to treat problems followed by *Persea americana* Mill, with CI=0.682 (58UR) which is used to treat gastric problems.

The collected information represents a base of knowledge for future research in the ethnobotanical field in the state, and it will contribute to the understanding of proper usage of medicinal plants. This study proved that the knowledge on medicinal uses of plants is not strictly related to isolated communities. When knowledge is transformed in goods, culture, income and health it can be promoted through the demand of tourists that visit the place searching better options to treat their ailments.

**Keywords:** Ethnomedicine, indigenous communities, Totonacapan

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## Ecological Wastewater Treatment by Tree-Root-Filter - Sustainable Sanitation-Solution for the Tropics

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Tropical inlands reveal the minor indices for sewage treatment of the world. In the tropics, results of conventional wastewater treatment facilities are weak, because of their need for secure energy and specialists for maintenance and monitoring. Our proposal of ecological wastewater treatment (EWT) promotes the natural purification of organic effluents in order to root oxygen release of some tropical amphibian plants. They create a decomposer/mineraliser - biocoenosis around their roots (periphyton), as detected in most weeds of swampy sites. Munguba, *Pseudobombax munguba* (Mart. & Zucc.) Dugand, a native tree species from the Amazonian floodplains of Brazil, has been identified as the best potential subterranean oxygen provider. In our EWT facility, the tangle of roots of *P. munguba* constitute a real root-filter. In an anticipated anaerobic primary treatment, the crude wastewater transforms in a mineral-sediment free solution. After the effective root-filter treatment, the exposition of the effluent to solar radiation in a vertical aquarium indorses disinfection and molecular sulphur precipitation. Several treatment plants have been established in Manaus City. They show best results and functionality, especially in comparison to conventional treatment facilities. Additionally, the nutrient absorption and resulting accelerated growths of the trees may be used for commercial exploitation of cellulose, timber and fruit production. People themselves can provide easy maintenance to EWT. The study presents the elements of the EWT and discusses the treatment results. We expect to promote EWT as the best option for wastewater treatment in the tropics, as it is totally independent from electrical energy and moving parts. Actually, we run studies by transforming wastewater-treatment investment in commercial production of fine fibres, as a base for sustainable development.

**Keywords:** Autodepuration, biotic oxygen release, environmental service, Munguba, root zone

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# The Impacts of Forest Landscape Changes on Ecosystem Provisioning Services in the North Central Mountainous Areas, Vietnam

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The research focuses on assessing the impact of forest landscape changes on other land use types, and on evaluating forest ecosystem provisioning services in the northern central mountainous area of Vietnam. We selected three different forest types (e.g. rich, medium, poor) to carry out the forest inventory in A Luoi District. A series of sample plots with the size of 1000 m<sup>2</sup> were randomized in each forest type. The forest inventory parameters consist of trees with diameter at breast height (DBH)  $\geq$  10 cm, regeneration trees with DBH of 1.3-9.9 cm, counting of all saplings  $\leq$  1.3 cm DBH, and non-timber forest products (NTFPs). The forest inventory variables (i.e. DBH, height, species, quality, slopes, elevations, aspects) are based on the national forest inventory and FAO's forest inventory manual. The demands of local peoples on the forest provisioning services were surveyed for different targeted groups living near the forest landscapes. We evaluated if the changes of land use patterns and forest landscape impacts on the demand of provisioning services (i.e. timber products, wild foods including NTFPs) to the local people. A time-series of different remote sensing images (Landsat, SPOT and Sentinel 2) are used to classify forest landscapes and land use types such as non-forest land, agricultural land, crop land, water area, grass land. Multiple regression analysis of variables of sample plots against the vegetation indices and demands of forest provisioning services at target groups were analysed in R-Studio 3.4.1 and Statistica 13.3. The result shows that the change in the forest landscape leads to changes of ecosystem services demands.

**Keywords:** Ecosystem provisioning services, forest landscape, forest types, land use change

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## Effect of Plant Density and Spring Planting Dates on Yield and Morpho-Physiological Traits of Garlic (*Allium sativum* L.)

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In order to investigate the effect of different planting dates and plant density on yield as well as on some morpho-physiological traits of garlic, a split plot experiment was conducted with three replications. The experimental treatments were three planting dates (March 5, March 25 and April 14) and four planting densities (20, 40, 60 and 80 plants  $\text{m}^{-2}$ ). The results showed a significant interaction between planting date and planting density for: garlic yield, leaf weight, plant height, total chlorophyll and carotenoids, whereas for harvest index, number of produced cloves in plant, chlorophyll a and relative water content only the effects of planting date and plant density were significant. The highest garlic yield ( $921 \text{ g. m}^{-2}$ ) was observed for planting date of March 5 with a density of 80 plants  $\text{m}^{-2}$ , but the lowest yield ( $317 \text{ g m}^{-2}$ ) was obtained for the last planting date with the lowest plant density. Similar results were observed for leaf weight. The highest amount of chlorophyll ( $2.52 \text{ mg g FW}^{-1}$ ) was observed for planting date of March 25 with the density of 20 plants  $\text{m}^{-2}$  but the planting density of 80 plants  $\text{m}^{-2}$  in the last planting date resulted in the lowest amount of total chlorophyll ( $2.07 \text{ mg g FW}^{-1}$ ). The highest harvest index was related to the first planning date and with delay in planting date, this index was reduced significantly. The lowest number of cloves per plant (3.64) was related to the last planting date. Increasing plant density also decreased the number of produced cloves by 14 percent. In terms of garlic yield, the best planting date in the studied region (with Mediterranean climate) was March 5<sup>th</sup>. Although increasing plant density resulted in higher yield, because of smaller size of produced bulbs the marketable yield decreased.

**Keywords:** Agronomic practices, harvest index, medicinal plants, relative water content

## Effects of Auxin Treatments and Cutting Types on Rooting of an Endangered Species (*Glyptostrobus pensilis* K.Koch)

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*Glyptostrobus pensilis* K.Koch (Chinese Swamp Cypress) is listed as “critically endangered” in Vietnam’s Red Data Book and also in the IUCN Red List of threatened tree species. This species is of high conservation concern due to their rarity and threats to their survival in terms of environmental changes such as habitat loss from expanding cultivation, felling and fires. There are only 164 mature individuals of *G. pensilis* in Dak Lak province, Vietnam and no regeneration has been found in studies, recently. Therefore, study on breeding techniques for *G. pensilis* by cutting is needed. Experiments was conducted in Tropical Forest Research Centre in order to assess the effect of (1) various concentrations of IBA (3-Indole butyric acid) and NAA (1-Naphthalene acetic acid), (2) cutting seasons (dry season and rain season), and (3) cutting types (softwood, semi-hardwood, and hardwood) on rooting percentage. The results showed that IBA with a concentration of 1.000 ppm produced the highest rooting percentage (67 %), followed by 20–27 % of rooting percentage was recorded in various NAA concentrations, while no rooted cuttings were found in the control treatment. Significant difference between dry and rainy season was found, the rooting percentage in the dry season is higher than that of the rainy season, with the rooting percentage of 38–41 % and 26–28 %, respectively. Concerning cutting types, the rooting rate of softwood and semi-hardwood was significantly higher than that of hardwood cuttings. The results from this study could potentially be used as basic information on the conservation of *G. pensilis* in future time.

**Keywords:** Auxin treatment, cutting seasons, cutting type, *Glyptostrobus pensilis*

## Current and Potential Spatial Distribution of Pollinators in Bolivia Influenced by Land-Use and Climate Change

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Animal pollination represents a key regulating ecosystem service, involved in wild plant reproduction and responsible for more than 35 % of world crop production. Recently, an increasing decline of pollinators has been evidenced. Although, global changes such as land-use and climate are known to have important impacts on pollinator communities, clear relationships between these drivers and pollinator loss remain little investigated. The present study aims to determine the effect of land-use and climate change on current and potential spatial distribution of pollinators in Bolivia. To do this, species distribution modelling and two scenarios based on projections suggested by the Fifth IPCC Assessment report for the year 2050 and 2080 were applied. The following data was combined in MaxEnt software package: a) presence-only records corresponding to three groups of pollinators (bees and wasp, butterflies and hummingbirds) obtained from open access databases such as Predicts project, GBIF and published papers; b) environmental variables derived from remote sensing techniques: temperature, precipitation, and land-use cover. In general, the results show that the actual status of pollinators in Bolivia is threatened by land-use and climate conditions, especially in eastern regions, where extensive land-use (agro-industrial activities and deforestation) and increase in temperatures have been observed. According to the analysis, there is a reduction of the geographic range of pollinators, although differences in response among groups are detected. Bees and wasps seems to be less susceptible to climate change in comparison to butterflies and hummingbirds. Under future scenarios 2050 and 2080, a moderate to extensive shift of pollinators range was observed, mainly in hummingbirds whose habitat might be reduced enormously as result of change in suitable environmental conditions. Here, we show how species distribution modelling could be applied as a useful tool to support decisions on pollinator conservation, particularly during the decision-making process.

**Keywords:** Climate, land use change, pollinators, species distribution modelling, tropical region

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## The Potential of Optimising Connectivity Conservation Using Unmanned Aerial Vehicle - A Case Study in Itaocara, Brazil

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Forest ecosystems host high level of biodiversity providing numerous ecosystem services. Globally, forests experience intense fragmentation due to various human activities such as expansion of agricultural and development areas. This also applies to Brazil's Atlantic Rainforest, one of the most biodiverse centers of Brazil that currently has around 12 % of its natural vegetation left. The ongoing loss of forest cover, prompts the need for more efficient techniques to preserve biodiversity. The last decade saw a growing number of research on connectivity conservation. In the context of forest ecosystems, several studies have shown the effects of different forest features on biodiversity distribution and dynamics. However, so far there is no indicator set linking forest features to connectivity conservation concepts. Apart from that, limited availability of data for the assessment of biodiversity at small scales poses a major challenge to ensure optimisation of biodiversity conservation. Recently, the use of unmanned aerial vehicles (UAV) and geographic information system (GIS) are seen as important tools to improve data collection and assessment in connectivity management. This study conducted in Itaocara Brazil aims to develop a methodology to measure forest quality in order to assess the feasibility of implementing *in-situ* conservation measures like designated Private Reserve of Natural Heritage (RPPNs) areas. In a first step, this research develops a weighted indicator set of forest characteristics that affect overall biodiversity. Data for the selected indicators (forest density and size, vegetation height and cover, indicator vegetation) has been acquired by means of UAV and ground truth. This approach allows to draw conclusions on the applicability of using aerial images for the assessment of forest characteristics. Since RPPNs designated areas are located within private properties, interviews with landowners were conducted to get an indication of the social acceptance of the proposed measure. Finally, by using least cost path method, connectivity maps were developed taking the results of the interviews into account. The results show UAV can be an important tool for connectivity conservation. Additionally, generated maps illustrate that consideration of social acceptance plays a major role in development of conservation measures.

**Keywords:** Biodiversity, indicator set, private reserve of natural heritage

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## Genetic Variability of *Myrciaria dubia* in Peruvian Amazon

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Camu-camu (*Myrciaria dubia* McVaugh) is one of the most important fruit species from South America. The production is focused in the Peruvian Amazon, Brazil and Bolivia. This species is particularly important for its high content of vitamin C and antioxidants. The breeding process begun in 1998. Most farmers use non-cultivated plants, usually taken from the wild or just make basic selections. The aim of this work was to characterise the genetic variability of wild and cultivated populations in the Peruvian Amazon. The analysis is focused on diversity within and between the populations. This work is based on a collection of 31 populations. 21 wild populations coming from the surroundings of the city of Iquitos, 2 populations as a representative of cultivated populations also from around that city, and the remaining 8 were collected from plantations nearby Pucallpa. For the genetic analysis, 10–15 individuals were randomly selected from each of the population and samples of leaves were taken from each one ( $n = 357$ ). For the detection of genetic diversity, six SSR primers were used, which have already been developed and used for a previous study at our university. By using computer programs, the main variability indexes and the related dendrogram were created.

The results showed that the observed heterozygosity (0.50) was smaller than the expected heterozygosity (0.61) and the inbreeding coefficient reached higher values in wild populations than in the cultivated ones. Wild populations could be divided according to the dendrogram into different groups. Approximate origin of cultivated populations was determined. The results showed also that the genetic variability is high, on the other hand there is also a high degree of inbreeding. This can be caused by large distance between populations from each other or low number of individuals in the population. This high level of diversity gives us a lot of possibilities in selection and breeding of the most profitable individuals.

**Keywords:** Camu-camu, genetic diversity, PCR, population genetics

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## Shifts in the Swiddens with Intensification: What Evidence Exists for the Trenbath Model?

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In the humid tropics, smallholder farmers traditionally use shifting cultivation. Increases in population density, intensification and greater market orientation have modified this system. In Cameroon, for example, farmers are recultivating fallows earlier, adopting the use of inorganic fertilisers, herbicides or weeding more frequently, and occasionally incorporating mechanised tillage, precluding the traditional retention of trees in the field. Different models predict the effect of intensification of shifting cultivation systems on soil fertility and fallow vegetation. For example, Trenbath (1985) and more recently Albers and Goldbach (2000), have postulated that with intensification, repeated cropping cycles and shortening fallow phases, a “spline point” will be reached at which tree regeneration fails completely and there will be a regime shift to a grassland domain. However, neither of these models has been tested empirically. Our objectives were: to assess impacts of intensification in shifting cultivation systems on fallow vegetation in the humid and sub-humid tropics; and, to assess how strongly Trenbath’s model is supported by empirical data. A systematic review in Web of Science was conducted for primary literature sources and articles analysing these effects. Most studies derived from Brazil and Madagascar with continental Africa underrepresented. With intensification, a decrease in fallow biomass was observed. Changes in species richness were not discernible, however, intensification decreased species evenness. This can partly be attributed to an increase in herb-dominance with intensified shifting cultivation, and a shift in species composition. Tree density decreased with intensification with a shift in composition towards those with a high sprouting capacity and vegetative propagation. Evidence that increased number of cropping cycles, longer cropping duration, intensified tillage practices with the application of fertilisers led to permanent grasslands, as suggested by Trenbath, was not found. Although an irreversible change was not observed, the intensification of shifting cultivation decreased biomass accumulation rates of fallows worldwide.

**Keywords:** Fallow succession, intensification, shifting cultivation, Trenbath’s model



## Biodiversity of Sea Buckthorn (*Hippophae rhamnoides* L.) in the Karakorum Mountains of Northern Pakistan

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Sea buckthorn (*Hippophae rhamnoides* L.) is a dioecious, wind-pollinated deciduous shrub species in Eurasia, including the Karakorum Mountains region of Pakistan (Gilgit-Baltistan). Contrary to other countries such as China and Germany, where it is considered as medicinal (especially fruits) and traded on national and international scales, in Pakistan this species is heavily underutilised. Moreover, a striking diversity of coloured berries in Pakistan from red to yellow raises the question: which varieties might be more suitable for different national and international markets. Therefore, both morphological and genetic diversity of sea buckthorn were studied to characterise and evaluate the present variability, including hypothetically ongoing process of domestication. Three hundred sea buckthorn individuals were sampled from eight different sites and distinguished each into wild and supposedly domesticated (within villages) stands. Dendrometric (height, stem diameter, canopy area), fruit (20-berry weight, volume, length: width ratio and moisture %) and leaf (area and length: width ratio) morphometric traits and leaf samples were taken for each individual. Twelve EST-SSR markers were used for genotyping. Significant differences in morphological variables were found across sites and between wild and village stands. A significant correlation ( $r = 0.493$ ,  $p < 0.001$ ) was found between leaf area and altitude. Twenty-two colour shades of berries and, 20 and 15 dorsal ventral colour shades of leaves, respectively, were observed using a Royal Horticultural Society (RHS) colour charts. Mean number of private alleles was 0.6 and mean genetic diversity of sea buckthorn within populations measured as an expected heterozygosity was high ( $H_e = 0.699$ ). Overall, the populations were in a Hardy-Weinberg equilibrium suggesting random mating within populations with a moderate level of differentiation ( $F_{ST} = 0.016$ ). However, three distinct genetic clusters were observed that apparently corresponded to the geographic locations of the populations. Interestingly, the two sites that had the lowest values of fruit and leaf morphometric parameters formed a genetically distinct cluster. Physical barrier appeared to be the cause of reduced gene flow. Considering high allelic richness and genetic diversity, the Gilgit-Baltistan region seems to be a promising source for improved germplasm of sea buckthorn.

**Keywords:** Domestication, EST-SSR markers, gene flow, Gilgit-Baltistan, morphological and genetic diversity

## Historical Forestry Research from the Belgian Colonial Period in the Democratic Republic of Congo

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Globally, forests influence climate change through complex, often nonlinear, forest-atmosphere interactions, such as carbon sequestration, decreased surface temperature through reduced solar irradiance and evaporative cooling. Likewise, climate change impacts forests in myriad ways, including shifts in plant phenology, changes in ecosystem productivity, and alterations in the geographic distribution of plant species. Trees are thus a unique living document of past and current climatic influences. The UNESCO biosphere reserves Yangambi and Luki are situated within the Congo Basin rainforest, which is the second largest rainforest in the world and presently a persistent carbon sink. Given its role as mitigator for global warming, reliably predicting how the Congo Basin rainforest will respond to climate change is key. Such predictions are complicated, however, by an apparent lack of eco-climatological baseline data for Central Africa. This data gap reflects the inaccessibility of such data, not the unavailability. In fact, forestry research in the Democratic Republic of Congo dates back to 1937, when the Institut National pour l'Etude Agronomique du Congo Belge (INEAC) created its Forestry Division. Particularly noteworthy are the long series of unpublished detailed phenological observations and daily climatological data records, both of which are unique on a global scale. Historical collections, located at the Royal Museum for Central Africa, the Botanic Garden Belgium, the National Belgian Archives, and in local herbaria in the DRC, provide data and insight into the dynamics of tropical forests and their resilience after disturbance. Here we report on current efforts to digitise and valorize data from forestry research carried out in the DRC between 1900–1960. We will address in particular the creation of the Forestry Division, as recorded in archival documents. We will also present an overview of the methodologies used by INEAC to collect phenological observations of trees, and arboreal samples.

**Keywords:** Climate change, legacy data, tropical forests, UNESCO bioreserves

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# Renewable Energy Recovery Generation for Security and Safety in Global Agriculture and Production: Justification and Outlook

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Waste is problematic in agriculture, production and remote-locations. Remote-power-generation cost is high due to diesel-fuelled gensets. With high premium on food-energy security and safety, the 330 kWe ERK®-ReGen container-power-plant improves waste management and lowers electricity-prices at these locations. Standardized components installed in multiple-containers enables high-quality, simple-transport and rapid-installation. The objective of this study is to present this renewable-energy-recovery-generation (ReGen)-design concept from evaluated resource-energy-use of some remote-areas of the world. A novel technique that combines resources and energy surveys with socio-economic-analyses was adopted in the technology properties and waste to identify and justify factors for the promotion and development of such techniques. Biomass and waste-materials were identified as inevitable products of society and are available in many remote-locations worldwide. Since substantial amounts of agriculture and production take place in remote-areas, a major challenge of the future is to understand how to manage large quantities of waste sustainably. Therefore, waste sources, their compositions and available waste-to-energy-technology options were researched. An approach has been to minimise the amount of waste produced and to recycle larger fractions of biomass and waste-materials. Renewable-energy-recovery-generation (ReGen) from waste can solve two problems at once; first is treating non-recyclable and non-reusable amounts of waste; and second is generating a significant (decentralised) amount of energy which can be included in the energy-production-mix in order to satisfy customers'-needs while keeping costs low. Interaction between waste-management-solutions and energy-production-technologies can vary significantly, depending on multiple-factors. ReGen is independent of fluctuating fossil fuel prices meaning energy-independence with reliable base load supply with the possibility of hybridisation for peak-demand to simultaneously solve the problems of waste, pollution and electricity generation. The diesel fuel substitution reduces CO<sub>2</sub>-emissions and sustainable-thermal-waste-disposal avoids ground soil-water contamination and marine pollution. The user-friendly, iconic ReGen-Plug&Play-system minimises installation time and enables relocation to new-sites. Emphasis should be placed on resource and energy-management-techniques that conserve the environment, foster food-energy security and safety. Therefore, policies that protect our oceans and land through sustainable resource and energy use must be emphasised. Sustainable foodenergy-production is a daunting challenge to global agriculture, industry and society and needs to be addressed in Africa and other remote-locations.

**Keywords:** Energy efficiency, ReGen - remote generation, safe production, waste to energy

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## Richness, Cultural Importance and Conservation of the Wild Spices in the Sudano-Guinean Zone of Benin

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In recent decades, wild spices (WS) have been increasingly studied for their flavor-enhancement characteristics and their medicinal properties. In Benin, many spices used daily for medicine, food and ceremony are gathered from the wild. But so far, little attempt has been made for their domestication and cultivation. Consequently, many WS are being extinct due to overexploitation and habitat loss. This study investigated the diversity of the wild spices as well as its ecological drivers, and document the associated traditional knowledge for their valuation, sustainable management and conservation in the Sudano-Guinean zone of Benin. Data were collected during field expeditions and using semi-structured interviews in ten localities across three phytodistricts. Occurrence data were recorded in the field and from Global Biodiversity Information Facility database. Species richness and Shannon's diversity index were estimated using species accumulation curves and based on presence-absence data obtained from semi-structured interviews. Species distribution and richness were then mapped, and their driving forces identified using conditional inference trees. Use-report and Cultural importance index were used along with a Generalized linear model to test for differences in traditional knowledge. Priority WS were identified using an approach combining eight criteria in four prioritisation methods. Fourteen species, belonging to 12 genera and 9 families were inventoried. The most prominent families were Zingiberaceae (21.43 %), Annonaceae (21.43 %) and Rutaceae (14.29 %). The species were unequally distributed and several spice-rich areas were identified. More than 200 specific uses were reported, with Tchabè people holding the greatest level of knowledge (70 uses; UR=5.70±0.33). The most culturally important spices differed among sociolinguistic groups. Overall, people perceived WS as declining due to agriculture, grazing and drought. Eight species were identified as of highest priority for conservation: *Aframomum albobviolaceum*, *A. angustifolium*, *A. melegueta*, *Lippia multiflora*, *Monodora tenuifolia*, *Securidaca longipedunculata*, *Xylopia aethiopica* and *Zanthoxylum zanthoxyloides*. This study provides basic data to engage conservation and domestication actions for WS in Benin. Priority species could be integrated into home gardens and traditional agroforestry systems in particular for sustainable management. However, for this to be effective, further research should be engaged on morphological and genetic diversity, and propagation methods of those spices.

**Keywords:** Biodiversity, conditional inference tree, ecological drivers, geographical distribution, prioritisation, quantitative ethnobotany

## Molecular Analysis of Gut Contents to Establish Host Range of Edible Grasshoppers in East Africa

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African grasshoppers (*Acanthacris ruficornis*) and long horned grasshoppers (*Ruspolia nitidula*) are important cultural food among communities in Kenya and Uganda. They are a good source of protein, fats, vital minerals and vitamins. Grasshoppers multiply during rainy season when there is enough moisture for eggs hatching and when grasses are available for them to feed. Despite their traditional importance as food, mass-rearing protocols for the species has not been developed. To optimise mass-rearing protocol, information on the preferred host crop of the grasshopper is critical. In this regard, we undertook molecular analysis of gut contents of *Acanthacris* and *Ruspolia* to identify their wild host plants. Adult insects were collected at different locations in Murang'a, Kenya and Mbarara, Kabale and Hoima, Uganda; preserved in absolute ethanol until further analysis. Grasshopper's guts i.e. fore-, mid- and hind gut were dissected from each specimen. Extraction of Plant DNA from the gut was done using the ISOLATE Plant DNA Kit from BIOLINE Company as per manufacturer's instructions. Forward and reverse primers, Mat K-1 RKIM-f and Mat K-3 FKIM-r respectively were used in PCR analysis. PCR products were purified and sequenced using Applied Biosystems 3730XL sequencer. Consensus sequences were generated using BioEdit software and the identity of plants established using basic local alignment search tool (BLAST) in the Genbank. Identified host plants of *Acanthacris ruficornis* were *Achyroopsis leptostachya*, *Heliocarpus pallidus*, *Centella virgata*, *Erigeron atticus*, *Galinsoga quadriradiata*, *Bougainvillea glabra* and *Digitaria exilis*. *Digitaria exilis* was the only identified host plant of *Ruspolia nitidula*. Most of the identified host plants were broad leaved species except *Digitaria exilis* which is a grass species. The identified wild host plants of these insects are available everywhere in the country hence they can be adopted for mass rearing of grasshoppers. Further studies should focus on assessment of preference to and growth of *Acanthacris* and *Ruspolia* on the identified host plants.

**Keywords:** *Acanthacris ruficornis*, gut contents, host plants, *Ruspolia nitidula*

## Understanding Variations in Plant Species Diversity in Homegardens of Smallholder Farms in Limpopo, South Africa

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Smallholder homegardens (HG) are perceived as important for *in situ* conservation of plant genetic resources and several ecosystem functions. Key to maintaining such functions is to understand the ecological, socioeconomic and management-related factors which influence the species diversity of HG. However, little is known about such factors, in particular for Southern Africa. This study first assesses plant species diversity of smallholder HG in the Limpopo province of South Africa and secondly examines its main determining factors. Six villages were selected across gradients of precipitation, wealth and access to infrastructures and services. A total of 127 households belonging to such villages were interviewed using semi-structured questionnaires to investigate their socioeconomic conditions and the management of the gardens. Additionally, an inventory was made of all “useful” plant species (including trees and ornamentals) of each HG and diversity indices were calculated. The effective number of species was then chosen as a measure of diversity and set as response variable in a linear mixed model investigating its determining factors. Likewise, the information from the household interviews was used to select a number of candidate explanatory variables encompassing climatic, socioeconomic and management-related aspects. Overall, 248 species were found, with maize being by far the most abundant crop (with a summed dominance ratio of 0.29) and indigenous species accounting for about 37.5 % of the total. Diversity was highest in the wealthiest villages and in those receiving the highest precipitation. Mean HG species richness of the surveyed villages ranged from 21 to 32, while Shannon diversity indices varied between 1.1 and 2.0, corresponding to mean effective numbers of species of 3.9 to 9.7 per garden. Among all the investigated factors, the most important determinants of diversity were irrigation intensity and monthly household income. In conclusion, improving household wealth and enabling an adequate access to water at the homestead, for example by providing electric pumps and promoting a responsible and efficient water use, seems to have a significantly positive influence on HG plant species diversity in Limpopo.

**Keywords:** Determining factors, homegardens, plant species diversity

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## The Spider Biodiversity in Long-Term Organic Rice Paddy Field in Subtropical China

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Spiders are one of the most important natural enemies in paddy fields and their diversity has declined due to pesticides application and agricultural intensification. Organic farming is considered as a promising solution for augmenting natural enemies in the agroecosystem. However, most of these studies were done in Europe, and more information is required regarding biodiversity in farming systems in non-European regions, particularly in the tropics and sub-tropics. It was hypothesised that the effects observed of agricultural practice on beneficial organisms may depend on the duration of the agricultural practices in organic farm over years. Therefore, we assessed spiders diversity of organic rice paddy field in subtropical China that had been cultivated organically for 5 (OR5), 10 (OR10) and 15 (OR15) years since conversion and compared it to conventional rice (CR). The results showed that abundance and richness of spiders in organic paddy fields were significantly higher than those of conventional paddy field. *Tetragnatha maxillosa* and *Pirata subpiraticus* were dominant in the spider assemblages in both organic and conventional paddy fields. Spider richness in OR5/OR10/OR15 was significantly higher than that in CR, and it increased with organic operation time, but the difference was not significant. There was no significant difference between Shannon Wiener index ( $H'$ ) of spiders in organic and conventional paddy fields. The findings of this study are consistent with most of the previous studies in showing that organic farming will improve biodiversity in comparison to conventional farming. The effect of organic farming practice on spiders' diversity over time needs further study before a clear conclusion can be made.

**Keywords:** Organic rice, spider diversity, subtropical

## Do Community Seed Banks Contribute to the Socio-Ecological Resilience of Communities? A Case-Study from Western Guatemala

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The region of Sierra de los Cuchumatanes (western Guatemala) has over the past decades seen a loss of its characteristic agrobiodiversity. Community seed banks (CSBs) were implemented to stop or reverse this trend and promote livelihood resilience. Our study is an enquiry into how CSBs contribute to sustainable agrobiodiversity management at community and household levels.

We conducted an in-depth comparative case study of three communities where CSBs have been implemented to explore how farmers have been affected by their establishment, using socio-ecological resilience as conceptual framework. We combined tools of participatory research and qualitative methods. The final data set comprised transcripts of 10 focus-group discussions and 86 semi-structured interviews, seed-network maps, CSB-timelines and the outcomes of three indicator-based self-assessment workshops on CSB-induced changes.

Our findings show that CSBs have an effect on local seed dynamics by fostering seed exchanges and providing access to new varieties. Other reported effects include improved information and knowledge exchange, and changes in gender roles and social organisation. Our results show that CSBs have a more direct impact at the household level rather than at the community level. They also make clear that in practice, implemented CSBs have a broader influence than originally planned. Still, challenges remain, such as involving the youth or including a wider range of crops that are important for income or nutrition.

The role CSBs (can) play is overshadowed by more fundamental changes in the socio-ecological system in the study area: the importance of maize cultivation and farming in general is diminishing, agricultural activities have become more individualised and market-oriented, and a large proportion of the youth is migrating to the United States. Traditionally, being self-sufficient in maize production has been an indicator of socio-ecological resilience. Today, however, remittances and a diversified household economy are dominant factors shaping resilience.

CSBs can contribute to this newly emerging resilience by strengthening livelihood diversification, improving technical and organisational capacities and contributing to more dynamic and effective networking. By doing so, the concepts of community seed bank and resilience acquire new meaning in the context of the larger socio-ecological change processes taking place in the region.

**Keywords:** Agricultural biodiversity, community seed banks, Guatemala, seed systems, socio-ecological resilience

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## Impact of Potato Crop Cultivation to Local Biodiversity in Musanze Province, Rwanda

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Agricultural intensification influences ecosystem status and biodiversity of the environment. The Virunga volcanoes area, where parts of it are situated in northern Rwanda, is a biodiversity hot spot in Africa. The system is challenged by increasing human activities to guarantee food security. Food security and biodiversity are dependent to each other in terms of e.g. biomass production. The objective of this study was to reveal differences in plant and insect diversity and to identify distinctions in vegetation structure between two determined treatments, the buffer zone of the volcano national park, which implicit the natural ecosystem and the potato crop area. Two methods were used to quantify different biodiversity values and to characterise the impact of potato crop cultivation on biodiversity at Musanze province in Rwanda. The method of vegetation mapping was applied, which offers, multi-usable information about vegetation structure and plant diversity. These indirect bio-indicators provide basic information on environmental status. The surrounding biotopes of the potato crop area and the buffer zone were mapped. By using barber-traps insect occurrence was analysed. Due to the catches the indicator species *Pterostychus*, a carabid beetle and the ant species *Pheidole megacephala* were defined. Out of their abundance it was possible to conclude about environmental status and soil condition. 56 insect species and 80 plant species were detected in the buffer zone compared to 40 insect species and 62 plant species in the potato area. The mean plant and insect abundance were also higher there. The measured structure coefficient was also higher in the buffer zone. In terms of the Vision 2020, Rwanda wants to intensify their agricultural production. It is questionable how conservation and intensification targets can be balanced. Every species provide important ecosystem services to e.g. produce biomass. Plant structures with a high diversity are unique resources for pollen or nesting sites and highly diverse ecosystems are more stable to pests and they are necessary to receive stable yields. It must be detected how the system can be intensified, with integrated pest management, artificial influences or a mix of them and how biodiversity with its ecosystem function benefit the agricultural system.

**Keywords:** Biodiversity, insect indicator species, potato-crop system, vegetation analysis, Virunga volcanoes

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# **Animal production**

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# Enhancing ruminant production

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## **Efficacy of Dairy Management Strategies to Increase Milk Yield of East African Dairy Cattle Smallholders**

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Although East Africa (EA) is home to one of the most advanced dairy industries within sub-Saharan Africa, regional milk production does not yet meet the growing milk demand. Various dairy management strategies (DMS) have been introduced to improve milk yield (MY); yet, their efficacy to increase MY under prevailing husbandry conditions is unknown. Therefore, this study aimed at (1) identifying DMS presented in the literature for increasing MY of individual cows on smallholder farms in EA; and (2) quantifying the increase in MY that can be achieved by these DMS.

Twenty-five studies from EA, that investigated increments in MY of a total of 2280 dairy cows in response to various DMS, were identified via a quantitative literature review. Data on measured MY (i.e. response variable), together with applied DMS and biophysical variables (i.e. explanatory variables) were extracted and processed by curtailing the standard errors of the mean MY of individual cows. Then, different weighting strategies were applied to prevent overweighting of particularly precise studies. Four multivariate causal regression models each differing in the weighting strategy (i.e. no weighting, number of observations, inverse of standard error, and inverse of the mean of standard error) were then fitted to explain the changes in MY associated with the use of DMS under different husbandry conditions. The best model was selected using the Akaike information criterion.

Nine DMS were identified, of which only the use of improved cattle breeds' and enhanced cattle nutrition (i.e. improving feed intake and diet nutritional quality), jointly explained MY increases per cow by up to 4.9 kg d<sup>-1</sup> ( $p < 0.05$ ). Other DMS (e.g. fodder crop use, watering regime, and parasite control) were not retained in the models. The model fitted without a weighting factor most accurately explained observed increments in MY by combining use of improved cattle breeds', enhanced cow nutrition when also accounting for trial length, and maximum ambient air temperature.

Use of improved cattle breeds and enhanced animal nutrition most effectively increase MY of smallholder dairy cattle in EA. These DMS should be combined to balance dairy cattle genetics, husbandry conditions, and cow nutrition to considerably improve cow performance.

**Keywords:** Dairy cows, dairy management strategies, East Africa, milk yield

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## Enhancing Small-Scale Sheep Production in Ethiopia Using Local Feed Resources

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There is a growing demand for sheep meat in Ethiopia, due to the cultural preference, increasing population, urbanisation and income. This calls for commercialisation of otherwise predominantly subsistence sheep production to meet the rising market demand and enhance income of the producers. Fattening sheep is one of the key strategies of adding value to the lean animals to meet specifications of the available markets while fetching better prices for the farmers. However, feed shortage is a major barrier. Therefore, there is need to find local feed resources that are affordable to small scale farmers. This study evaluated the impact of three browses namely; *Cordia monoica*, *Cordia uncinulata* and *Dichrostachys cinerea*, on the production performance of sheep fattening. Barley-straw was used as the control diet. One year old abergelle breed sheep weighing  $14.1 \pm 0.72$  kg were fed on feed rations of barley-straw supplemented with 200g of each of *C. monoica*, *C. uncinulata* and *D. cinerea* for a period of 15 weeks. Mean separation test analysis shows that the daily intake of total dry matter of the sheep fed with supplemented diet (8.73g) and those fed on control diet (4.9g) were significantly different ( $p < 0.001$ ). Dry matter digestibility for the *C. uncinulata* and *D. cinerea* supplemented diet was significantly higher ( $p < 0.0001$ ) than the diets supplemented with *C. monoica* and the control diet. Similarly, the *C. uncinulata* and *D. cinerea* supplemented diet had significantly higher ( $p < 0.0001$ ) apparent crude protein digestibility than the *C. monoica* diet and control diet. The sheep fed with *C. uncinulata* and *D. cinerea* had the highest mean slaughter weight, empty body weight and hot carcass weight. A partial budget analysis shows that every dollar spent on *C. uncinulata*, *D. cinerea* and *C. monoica* supplementation gave a return of USD 4.00, 3.28 and 0.53, respectively. Supplementation of sheep feed with *C. monoica*, *C. uncinulata*, and *D. cinerea* not only improves weight gain, but is also cost effective in enhancing productivity of small scale sheep production in response to the rising mutton market demand in Ethiopia. If browse production, processing and use are technically and institutionally supported, there is a potential for enhancing sustainable and market-oriented small-scale sheep production in Ethiopia.

**Keywords:** Browses, Ethiopia, market, sheep

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## Association of KiF12 Gene Related to Fatty Acid Composition in Javanese Fat Tailed Sheep

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Kinesin-like protein KIF12 gene are suggested as candidate gene involved in fatty acid metabolism. The aim of this study was to analyse the genotype polymorphism and to study association of KIF12 gene (g.9617965 C>T) related to fatty acid composition. Thirty five Javanese fat tailed sheep rams were used in this study. Identification of gene polymorphism and associations of KIF12 gene was performed using polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) method and general linear model (GLM) analysis. The results of the identification of KIF12 gene polymorphism are polymorphic. The results showed that there were three genotypes (CC, CT, and TT) found in this study. Association analysis showed that KIF12 gene was significant ( $p < 0.05$ ) associated with unsaturated fatty acids including Miristoleic acid (C14:1), Oleic acid (C18:1n9c) and saturated fatty acid including Lauric acid (C12), Myristic acid (C14), and Heptadecanoic acid (C17). The genotype CC exhibited greater the unsaturated fatty acid Miristoleic Acid (C14:1) and the saturated fatty acids Lauric acid (C12) and Myristic acid (C14) than the genotypes CT and TT ( $p < 0.05$ ). The genotype CT exhibited greater the unsaturated fatty acid Oleic acid (C18:1n9c) and the saturated fatty acid Heptadecanoic acid (C17) than the genotypes CC and TT ( $p < 0.05$ ). These results will improve the understanding of the functions of the KIF12 gene in fatty acid metabolism especially in terms of unsaturated fatty acid and will shed light on KIF12 as a candidate in the selection of sheep with high unsaturated fatty acids in Javanese fat tailed sheep.

**Keywords:** Association, fatty acid composition, Javanese fat tailed sheep, KIF12 gene

## Developing Innovative and Sustainable Approaches to Prevent the Spread of Goat Plague Disease in Democratic Republic of Congo

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Peste des petits ruminants (PPR) or “goat plague” is an acute viral disease of small ruminants caused by PPR virus (PPRV). The disease causes high morbidities of up to 100 % and mortality rates ranging between 50 and 90 % in goats and sheep leading to high economic losses. The disease was first reported by FAO and OIE in the Democratic Republic of Congo (DRC) in 2008. The aim of the current study was to confirm and characterise PPRV using reverse transcriptase polymerase chain reaction (RT-PCR) and to establish their phylogenetic relationship by sequencing the nucleoprotein (N), fusion (F) and hemagglutinin (H) genes but also evaluate the prevalence of PPRV specific antibody by competitive enzyme-linked immunosorbent assay (cELISA) and determine specific in-country risk factors associated with the disease patterns. Samples including oculonasal swabs, tissues and whole blood were obtained from live goats and/or sheep with clinical presentation suggestive of PPR for virus characterisation and serum for antibody-PPRV detection. The clinical signs observed in sampled goats and/or sheep suspected with PPR included proliferative and self-resolving lesions around the muzzle and lips of involved animals, serous mucopurulent nasal and ocular discharge, fever, diarrhea, lacrimation, matting of eye lids, cutaneous nodules, erosions on the soft palate and gums and labored breathing. The screening of 150 samples by RT-PCR indicated an overall prevalence of 64.7 %. Phylogenetic analysis based on the sequencing of N, F and H genes indicated that PPRV obtained from Eastern DRC clustered genetically with PPRV strains of Lineage III, together with PPRV from East Africa. Therefore the control of this disease is important in order to avoid the spread of the virus in the entire country and across. An overall PPRV seroprevalence of 45.3 % (n=320) was determined. A multilevel nominal logistic model using JMP-Pro software and Stata 11 indicated that the likelihood of goats and sheep being infected with PPRV increased significantly when animals shared water sources, herd size increased, animal age increased, exotic breed, communal grazing systems and farm-to-farm animal exchange. PPRV is circulating in South Kivu and several risk factors are associated with its sero-status including spacial and farm management.

**Keywords:** Democratic Republic of Congo, molecular characterisation, peste-des-petits ruminants, risk factors, seroprevalence

## Phenotypic Dairy Cattle Trait Expressions in Dependency on Rural-Urban Gradients

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In dairy cattle breeding programs in Europe or in North America, phenotypic trait expressions have been studied within distinct environmental classes, e.g., conventional versus organic production systems. The aim of the present study was to enhance such concepts via trait modelling in dependency of continuous explanatory variables, considering both social and ecological descriptors simultaneously. Obvious social-ecological challenges for dairy production due to obvious social-ecological heterogeneity might exist in rising megacities on rural-urban gradients. Consequently, following the logic of rural-urban indexes, a simplified survey stratification index (SSI) was calculated based on building density and distance to the city centre for the chosen megacity Bangalore, located in the South of India. Dairy trait recording focused on the generation of a longitudinal data structure, covering a recording period from June 2017 to February 2018, and including 391 dairy cows from 105 herds in urban ( $SSI < 0.3$ ), mixed ( $0.3 - 0.5$ ) and rural ( $SSI > 0.5$ ) districts. Traits from repeated farm visits reflected the categories production (daily milk yield: MY), energy efficiency (body condition score: BCS), cow wellbeing (udder hygiene score: UHYS, leg hygiene score: LHYS), and health (locomotion score: LOC, mastitis: MAST). The statistical models for repeated measurement analyses considered the fixed effects of lactation, days in milk, breed, year-season of trait recording, and SSI as a covariate. For SSI, different functions based on Legendre polynomials 1 to 4 were tested in consecutive runs for all traits. Random effects included the cow (genetic plus permanent environment), the herd, and the residual component. Model evaluation criteria were AIC and BIC values. Throughout smallest AIC and BIC values indicating model superiority were achieved with Legendre polynomials of order 1 (reflecting a linear regression) and of order 4. Quadratic functions (Legendre 2) were associated with large AIC and BIC values for all traits. MY and BCS were higher in the urban regions, associated with reduced MAST and better hygiene scores for UHYS and LHYS. Such obvious differences in phenotypic trait expressions due to social-ecological heterogeneity might contribute to a deeper understanding of physiological mechanisms underlying genotype by environment interactions.

**Keywords:** Dairy cattle, rural-urban farms, social-ecological systems, survey stratification index (SSI)

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## **The Effects of Nano Selenium on Performance and Immune System of Suckling Holstein Dairy Calves**

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The aim of this research was to consider the effects of Nano Se (NS) supplemented on colostrum and milk during first 30 days of life based on the performance and skeletal growth and also its effects on hematological parameters, blood Se concentration, total antioxidant status (TAS), glutathione peroxidase activity (GPX) and serum immunoglobulin G (IgG) in suckling Holstein calves. Therefore, twenty four newborn calves were randomly assigned with the following treatments C= control (no supplementation and selenium derived only from milk and concentrate); NS 0.2=0.2 mg of Nano Se/animal per day to the colostrum at first day and then to milk; and NS 0.3=0.3 mg of Se/animal per day to the colostrum at first day and then to milk. The blood concentration of Se was higher in the NS 0.2 and NS 0.3 treated animals than in the control animals ( $P = 0.05$ ) at 30 days of age. TAS was higher in NS 0.3 treated animals compared to NS 0.2 and control animals at 30 day of trial ( $P = 0.05$ ). GPX activity during the 30 days of the research was higher in animals receiving NS supplementation compared to the control animals during the 30 days of the experiment ( $P = 0.05$ ). And also serum IgG was higher in the NS 0.2 and NS 0.3 treated animals compared to the control animals ( $P = 0.05$ ) at 0 and 3 days of age. No difference was observed in the DMI, WG, WH, HG and BL among treatments regimes when the calves were 0, 15 and 30 days old. Feed conversion (FCR) was more efficient in NS treated animals than in control animals during the 30 days of age. There were no significant differences in platelet cells, hemoglobin, red blood cells, white blood cells, packed cell volume, neutrophils and lymphocytes among treatment regimes at 0, 15 and 30 days of age. Selenium supplementation also did not act as a growth promoter but did improve TAS status, GPX activity, serum IgG and blood Se concentration in treated animals with NS during this phase of compromised health.

**Keywords:** Glutathione peroxidase activity, immune system, performance, total antioxidant status

## Feed and Management Interventions for Increased Milk Production in Zebu Cattle at Ibadan

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Milk production in Zebu cattle is limited by their low genetic potentials, poor nutrition and poor management practices. In Nigeria, cattle are grazed extensively on low quality native pastures which have low protein content and poor digestibility. This is further complicated by poor water supply, endemic parasite infestation, heat stress and scarcity of forage during the dry season. Under these conditions, productivity of Zebu cattle is predictably low. In order to minimise the negative effects of poor nutrition and stressful environment, different feeding and management interventions were introduced at the University of Ibadan, to improve milk production and general performance of Zebu cows or heifers. These include fodder cropping, silage production, tick control measures and evaporative cooling of cows. Fodder cropping, particularly, elephant grass (*Pennisetum purpureum*) was found to be suitable for silage-making and fresh-cut feeding of cattle. Introduction of silage into the diet improved growth rate of Zebu heifers by 100 % (400–800 g d<sup>-1</sup>) and milk yield of cows by about 125 % (average of 2.0–4.50 kg d<sup>-1</sup>). Tick control measures and evaporative cooling of heifers during hot weather also enhanced growth rate by an average of 121 % (av. 300–663 g d<sup>-1</sup>) and 64 % (av. 380–643 g d<sup>-1</sup>) respectively. Evaporative cooling also enhanced animal comfort and dry matter intake of Zebu heifers in the hot environment. Rectal temperature of heifers dropped from 39.3°C to an average of 38.3°C in the afternoon when cooling measures were applied while dry matter intake increased from 2.08 to 3.78 % of body weight. These interventions when adopted have great potentials to enhance productivity and milk output from Zebu cattle in Nigeria and other tropical countries.

**Keywords:** Evaporative cooling, milk yield, silage, tick control, Zebu cattle

## Evaluating the Traditional Feed Storage Systems of Grain Legume Fodders in Northern Ghana

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Feed scarcity and high feed costs, especially during the dry season, are major challenges to ruminant production in West Africa. Crop residues are tradable commodities, and they are commonly used as an alternative feed source in the absence of grazing resources. The residues of grain legumes, also known as grain legume fodders (GLFs), such as groundnut and cowpea haulms, have a better nutritional quality than cereal residues, such as maize and rice straws. Little is known, however, about the impact of different feed storage systems on the nutritional quality of GLFs. We, therefore, evaluated the effects of location (rooftop, tree fork and room) and type of storage (packed sacks and unpacked, but tied with ropes) on the nutritional quality of GLFs (cowpea, groundnut and soybean fodder) stored for four months. Each month, stored fodders were weighed and sampled for quality assessment based on laboratory analyses and, ranked by groups of farmers based on indigenous quality indicators, such as colour, smell and leafiness. To determine palatability and dry matter (DM) intake, we also fed one kilogramme of each sample to 12 mature local sheep in a cafeteria fashion for 14 hours. Preliminary results indicated that room is a better storage location than tree fork and rooftop. Moreover, crude protein and organic matter digestibility decreased with length of storage time, across fodder types. DM loss during four months of storage was lower for sack storage (13 %) than for fodder tied with a rope (32 %), ( $p < 0.05$ ). Moreover, sheep consumed more cowpea fodder when stored in sacks (833 g DM day<sup>-1</sup>) than when tied with rope (741 g DM day<sup>-1</sup>). Similarly, sheep consumed more groundnut fodder when stored in sacks (761 g DM day<sup>-1</sup>) than when tied with ropes (649 g DM day<sup>-1</sup>). Farmers and their animals ranked cowpea fodder highest, followed by groundnut and lastly soybean fodder. To conclude, the nutritional quality of GLFs can be preserved if stored in sacks in a room for a period not exceeding five months. This study provided insights into better storage practices to maintain fodder quality in feeding systems to enhance livestock production.

**Keywords:** Fodder quality, grain legume residues, livestock feed, storage

## Genetic Variability of $\beta$ -Lactoglobulin Gene in Sudanese Goat Breeds

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Sudanese indigenous goat breeds have an important contribution to food security, livelihood, and rural economy. The improvement of the productivity of goat local breeds contributes to rural development. Therefore, the identification of the genetic variations is important for genetic improvement of economical production traits. The aim of this study was to detect the variation of the goat  $\beta$ -lactoglobulin (LGB) gene in four Sudanese goat breeds (Nubian, Desert, Nilotic and Taggar goats). Genomic DNA samples from 20 animals were screened for the variability in the coding and upstream region of the LGB gene. This was done by comparative sequencing to the goat reference genome at NCBI.

The sequence analysis of 5,316 bp detected 30 SNPs in comparison to the reference sequence, with an average of 5.6 SNPs per 1,000 sequenced base pairs. We found eight SNPs in the upstream gene region, two synonymous SNPs, three in the 3'-UTR, and 17 in introns. Three out of eight SNPs at the upstream gene region were novel. One of the novel SNP and additionally SNP in the promoter region reside in putative transcription factor binding sites for M6097, Elk3, Elf5, and GABPA. These SNPs could affect the gene regulation, influencing the transcriptional rate, and hence may potentially influence the milk protein content. The novel synonymous SNP in exon 2 was found only in Nubian and Desert goats. Among the 17 SNPs in introns, nine were novel. The above mentioned findings show high genetic variability among Sudanese goats in the LGB gene which could potentially affect protein yield in goat milk production. Further research is required to identify the phenotypic effects of the novel SNPs found in this study.

**Keywords:** Beta lactoglobulin, genetic variants, single nucleotide polymorphism, Sudanese goat breeds



## Alternative Feeding System Effect on Productivity and Profitability of the Dairy Farming System in Bangladesh

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Dairy feeding systems in Bangladesh are highly complex and still mostly unidentified. A further problem constitutes the scarcity of year-round feed supply which might require adopting alternative feeding systems (AFS) to enhance dairy productivity. Therefore, the objective of this study was to estimate the effect of AFS on animal productivity and profitability and identify factors that affect adoption of AFS. To this end the International Farm Comparison Network (IFCN) methodology is applied which is based on the typical farm approach (TFA) and the technology impact policy impact calculations (TIPI-CAL) model. In addition, a binary choice logit regression model is used. A 'typical' farm operating with current feeding system (CFS) was used as baseline farm. The AFS introduces the concept of balanced ration, using the optimal proportion of locally available roughages and concentrates at the least cost. In contrast, the CFS relies on roughage feed, particularly rice straw, and does not use the concept of balanced ration. The data to model the typical farm were obtained from a panel survey on 12 typical farms. Data was analysed using the TIPI-CAL software (5.3) and STATA version 12.0. The results revealed that the adoption of AFS results in a 21 % higher milk production (8.2 kg/cow/day) than CFS (6.18 kg/cow/day), whereas costs are higher for CFS (48.8 US\$/100 kg Energy Corrected Milk, ECM) than for AFS (34.7 US\$ / 100 kg ECM). This implies that costs can be reduced by 29 % if AFS is adopted. The benefit-cost ratio was 1.69 for AFS and 1.16 for CFS, corresponding to a net return from milk production of 88 % for AFS and 40 % for CFS. Farmer education, milk price, return over variable cost (ROVC), predicted profit and Herfindhal index were significantly ( $p < 0.05$ ) influencing the adoption of AFS. Therefore, a suitable strategy needs to be identified to promote adequate adoption of AFS in order to render dairy production sustainable and thus ensure food and nutrition security among dairy farmers in Bangladesh and their customers.

**Keywords:** Current feeding system and alternative feeding system, dairy, milk productivity, profitability

## Milk Yield Gaps and their Determinants in Smallholder Farms in a Semi-Arid Ecosystem of Kenya

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Relative milk yield gaps computed as the difference between actual and potentially attainable yield provide insight of how much production can be increased in practice with locally available resources and technologies. We applied bench-marking approach with the principle that some farmers are able to attain higher productivity levels than the typical farmer despite facing similar resources, challenges and trade-offs. These top performing farmers likely do allocate production resources differently, which may inform prioritisation of promising intervention options from local production experiences for closing yield gap presently observed in milk production. The study quantified the magnitude in milk yield gap and to identify differences between top 10 % farms and typical farms that could point to the promising interventions for closing the milk yield gaps. The bench-marking approach was applied to survey data from smallholder dairy farms in a semi-arid region of Kenya. Milk yield per cow per day was 14.6 litres in the top farms and 6.3 litres in the typical farms, which translates to 57.4 % yield gap. This implies that a typical farm is currently producing at 42.6% below the potential attainable yield and has the potential to increase yields by 134.9 %. Paired comparisons of the least square means between the top and typical farms consistently showed that top farms invested more in external sourcing of feed, water and labour to supplement on-farm resources, veterinary services for disease control to improve herd health and in artificial insemination to improve breed quality. This demonstrates that the difference between top performing farms and the typical farms is use of external resources. At the present attained productivity levels, results show that farmers can more than double their milk yields through efficient use of external inputs and services. Therefore empowering farmers with knowledge, skills and networks that enable them to access and efficiently use external inputs and services is recommended for interventions targeting closing the yield gaps. This can be attained through strengthening farmer cooperative movement to ease access to input and output markets with check-off arrangements for payments.

**Keywords:** Bench marking approach, external inputs, survey data, top farms, typical farms

## Effects of Type of Concentrate Feed and Timing of Supplementation on Performance of Lactating Dairy Cows Grazing an Alfalfa-Rye-Grass Sward in the Peruvian Highlands

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Alfalfa is an important forage source for grazing dairy cattle in the Peruvian highlands. Moderate metabolisable energy contents and high concentrations of rapidly rumen degradable protein in alfalfa necessitate the supplementation of concentrates rich in non-structural carbohydrates. The aim was thus to evaluate the effects of two different cereal grains differing in ruminal starch degradation and timing of supplementation on milk yield of dairy cows grazing a mixed alfalfa-rye-grass sward.

A feeding trial was conducted at the research station of National Agrarian University La Molina in Jauja, Peru (11°51'36.3" South, 75°23'48.8" West; 3,350 m above sea level), between November 2017 to February 2018. The trial comprised three periods of 14 d adaptation and 7 d sampling and tested four treatments in a Youden Square design. Twenty-four lactating Brown Swiss cows were used with (mean  $\pm$  standard deviation) 458  $\pm$  48.4 kg live weight (LW), 141  $\pm$  52 days in milk, and 15.3  $\pm$  1.8 kg d<sup>-1</sup> milk yield at the start of the trial. All cows grazed an alfalfa-rye-grass sward for 8 h d<sup>-1</sup>. They were divided into four groups that were randomly assigned to one of the four treatments. Dietary treatments included 3.5 kg d<sup>-1</sup> (as-fed basis) of two types of cereal grains differing in starch degradation (i.e., ground corn (C) and oat (O)) along with 0.5 kg d<sup>-1</sup> (as-fed basis) of corn cobs. While two groups received their concentrate mixtures at 1 kg cow<sup>-1</sup> during morning and 2.5 kg cow<sup>-1</sup> and day during afternoon milking (Cpm, Opm), 2.5 kg cow<sup>-1</sup> of the concentrate mixtures were fed during morning and 1 kg cow<sup>-1</sup> and day during afternoon milking to the other two groups (Cam, Oam).

Mean daily concentrate intake was 3.2 (Cpm), 3.1 (Cam), 3.1 (Opm), and 3.3 kg DM cow<sup>-1</sup> (Oam). Mean daily milk yield was 15.6 (Cpm), 14.8 (Cam), 14.1 (Opm), and 15.0 kg cow<sup>-1</sup> (Oam). Timing of supplementation appears to affect performance of grazing cows, but the effect differs depending on the type of concentrate feed used. Results on milk composition, apparent total tract nutrient digestibility, and feed intake are still pending, but will be used to explain observed differences in milk yield.

**Keywords:** Dairy cows, grazing, non-structural carbohydrates, supplementation

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## Particle Size Distribution Is an Indication of Wheat Bran Quality Attributes for Dairy Farmers in Tigray Region, Northern Ethiopia

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This study was conducted to evaluate the relationship between farmers' preference and laboratory analysis for assessment of wheat bran quality parameters. A total of 30 smallholder dairy farmers were involved in the study. Five types of wheat bran were collected from five major wheat flour processing factories found in Tigray region (Ethiopia). Farmers scored the studied wheat bran types on a scale of 1 (not preferred) to 4 (highly preferred) for quality attributes including water holding capacity (WHC), swelling capacity (SC) and nutritive value. The laboratory analysis of wheat bran samples were conducted for physical parameters [geometric median particle size (D50), WHC, SC, water retention capacity (WRC) and bulk density (BD)], proximate and fibre components and *in vitro* digestibility. A difference ( $p < 0.05$ ) in D50, WHC, SC, WRC and BD among the studied wheat bran types was ensured. Ranges of the monitored physical, chemical and digestibility parameters are given between brackets: D50 (909–1103  $\mu\text{m}$ ), WHC (2.14–2.90  $\text{g g}^{-1}$ ), crude protein (CP) (133–163  $\text{g kg}^{-1}$  DM), ash free neutral detergent fibre (347–476  $\text{g kg}^{-1}$  DM), non fibre carbohydrates (265–436  $\text{g kg}^{-1}$  DM), effective rumen dry matter degradability (0.568–0.712  $\text{g g}^{-1}$  DM) and effective rumen protein degradability (ERPD) (0.730–0.793  $\text{g g}^{-1}$  DM). Farmers particularly relied on particle size distribution to make their appreciation and highly scored wheat bran types with coarse particle size for the quality attributes of WHC and SC, while, the wheat bran types with fine particle size distribution were generally better scored for their nutritive value. Farmers' scores for nutritive value of wheat bran were positively correlated with CP ( $r = 0.347$ ;  $p < 0.05$ ) and ERPD ( $r = 0.291$ ;  $p < 0.05$ ), whereas, there was a negative association with particle size ( $r = -0.553$ ;  $p < 0.05$ ). Farmers' scores for water holding capacity of wheat bran were positively correlated with particle size ( $r = 0.526$ ;  $p < 0.05$ ). Overall, the present findings revealed that particle size distribution is the predominant qualitative selection criteria for farmers to assess wheat bran quality (e.g. on the market) and this qualitative appreciation is to some extent related to chemical characteristics and rumen degradability.

**Keywords:** Nutritive value, particle size, water holding capacity, wheat bran

## Factors Influencing Breeding Decisions by Smallholder Dairy Farmers Across Four Countries in Sub-Saharan Africa

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The reported study aimed at determining and characterising factors that influence smallholder dairy farmers to choose between bull service and artificial insemination (AI) for cow breeding. Further, the relationships between the breeding choices and the bio-physical elements of dairy farming, mainly, farmer characteristics, farm management practices, institutional support structure and household income, were investigated. Data were collected in a large-scale survey through face to face interviews, from a total of 16,308 small scale dairy farmers in Ethiopia (n = 4679), Kenya (n = 5278), Tanzania (n = 3500), and Uganda (n = 2851). Chi-Square test and t-test were used to summarise the data while logistic regression and factor analysis were used to identify the determinants. Across the countries, results show a significant difference in animal husbandry practices between farmers who use AI and those who use traditional bull mating. Majority of farmers that used AI kept records, purchased more animal feeds, used more labour by hiring workers whose average wages were higher than those of bull service farmers. Farmers who used AI paid more for animal husbandry services such as water access and breeding compared to farmers who used bulls. The proportion of AI to bull service users was almost equal in Ethiopia and Kenya, while Uganda and Tanzania had more farmers who preferred bull service to AI. Within each investigated country, factors such as farmer's experience in dairy farming, influence of the neighbour, the farmer's ability to keep records, management practices such as water provision and availability of purchased feeds all had a significant association ( $p < 0.0001$ ) with AI adoption. However, a large herd size and large land size negatively influenced AI adoption. Institutional settings including cost of AI service and the distance that the service provider covered to the farm negatively affected ( $p < 0.0001$ ) the choice of AI as a breeding option. Also observed is that, there is a high likelihood of continued use of a specific breeding method with previous conception success. In conclusion, institutional support has a vital place in farmer breeding decisions. In future, universities have a role to play in providing relevant decision support tools.

**Keywords:** Artificial insemination, breeding decisions, small-scale farmers

## ***In vitro* Gas Fermentation Assessment of *Persea americana* Leaf and Acceptability by West African Dwarf Sheep**

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Ruminants in the tropics are slow growing, resulting from low quality feed. The use of indigenous multipurpose plants is a good strategy for an improved livestock performance. Chemical composition and coefficient of preference (CoP) of green, yellow and brown leaves of *Persea americana* (PA) by West African Dwarf Sheep were determined. *In vitro* gas production (IVGP) of green, yellow and brown leaves of PA were carried out over a period of 24 hr incubation. Metabolisable energy (ME), organic matter digestibility (OMD) and short chain fatty acids (SCFA) were predicted. 10 M NaOH was introduced into the inoculums after 24 hrs from which methane (CH<sub>4</sub>) production was measured. Results indicated that chemical composition ranged significantly ( $p < 0.05$ ) among the different forms of PA leaves. Dry matter ranged between 88.75 and 91.22 % in green and brown leaf respectively, same trend was observed for neutral detergent fibre, it ranged from 59.48 to 60.01 % in green and brown leaf respectively, while the crude protein ranged between 23.59 and 25.85 % in brown and green leaf respectively.

The CoP ranged between 1.58 in brown leaf and 2.01 in green leaf. The IVGP, ME, OMD, SCFA and methane production were not significant ( $p > 0.05$ ). Same trend was observed for all the *in vitro* gas production parameters with the green leaf recording the highest value, while the lowest values were obtained in the brown leaf. They ranged between 6.25 and 8.50 ml/200 mg DM; 3.73 and 3.96 MJ kg<sup>-1</sup> DM; 38.66 and 41.67 %; 0.18 and 0.22  $\mu$ mol; 2 and 4 ml/200 mg DM in brown and green leaf respectively.

The result of this study showed that all forms of *Persea americana* leaf have potential as prospective forage for ruminant production in the tropics .

**Keywords:** Acceptability, *in vitro* gas fermentation, leaves, *Persea americana*, WAD Sheep

## Applying *in vitro* Gas Production Technique to Assess the Nutritive Value of *Gmelina arborea* Leaves

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*In vitro* gas fermentation method was used to evaluate the nutritive value of different forms of *Gmelina arborea* leaves. Two experiments were conducted. Experiment 1 involved the determination of chemical composition of green, yellow and brown leaves. In experiment 2, the nutritive value of green, yellow and brown leaves of *Gmelina arborea* was assessed by *in vitro* gas production technique for total gas production over a period of 24 hr and to predict organic matter digestibility (OMD), metabolisable energy (ME) and short chain fatty acid (SCFA). Methane volume (CH<sub>4</sub>) was measured after incubation at 24 hr. The *in vitro* gas production (IVGP) characteristics (insoluble degradable fraction (b), potential degradability (a+b), rate of degradation (c) and effective degradation (ED)) were also predicted.

Results revealed that the chemical composition of green, yellow and brown leaves varied significantly ( $p < 0.05$ ). Dry matter ranged from 80.15 to 91.24% in green and brown leaf respectively. Same trend was observed for neutral detergent fibre, it ranged from 60.92 to 63.77%. The crude protein ranged from 24.84 to 26.44% in brown and green leaves respectively. The IVGP, ME, SCFA and methane production were not significant ( $p > 0.05$ ), except OMD. Same trend was observed for all the *in vitro* gas fermentation parameters with the green leaf recording the highest value, while the lowest values were obtained in the brown leaf. They ranged between 3.75 and 4.25 ml/200 mg DM; 3.27 and 3.49 MJ kg<sup>-1</sup> DM; 0.10 and 0.94  $\mu$ mol; 1.5 and 3.0 ml/200 mg DM in brown and green leaf respectively. OMD ranged significantly from 41.57 to 45.05% in yellow and green leaf respectively. The a, b, a+b, c and ED also did not vary significantly.

It can be concluded that *Gmelina arborea* leaf has potential in ruminant nutrition and any of the forms can serve as fodder in the tropics.

**Keywords:** chemical composition, *Gmelina arborea* leaves, *in vitro* gas production, nutritive value

## Characteristics of Dairy Farms along the Rural-Urban Interface of the Emerging Megacity of Bangalore, India

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While the beginning of agriculture initiated the first human settlements, maintenance of ecosystem services provided by agricultural production systems gets more complex with the fast urbanisation trend and corresponding diet changes of modern times. In Africa and Asia, megacities are emerging fast but still rely on (peri-)urban agriculture to supply their urbanised population; they offer the opportunity to gain deeper understanding of transition processes in agriculture. The aim of this study was to identify and characterise the multiple dairy production systems in the rural-urban interface of Bangalore with its high demand for dairy products, thereby focusing on their intensification level. Qualitative and quantitative survey data on socio-economic status of the household, resources availability, dairy herd composition and management, and in- and output markets were obtained from 337 dairy farms across six strata (1= urban to 6= rural). SPSS two-step clustering was applied to the dataset to identify major dairy production systems. Kruskal Wallis and Chi-squared tests were used to further characterise each system. Four dairy production systems were identified based on five main parameters: spatial location along the six strata, proportion of exotic breeds in the herd, cattle in- and outflow, use of pasture, and reliance (at least partial) on own production of forage. Strongest dichotomies between the dairy production systems were observed (i) in the reliance on own forage production: most of the dairy farmers at least partially supplied own green forage to their herd, while others bought it or relied on (free) market waste or forage collected from public places, and (ii) in the use of pasture: some dairy farmers, mainly the ones with a highly specialised herd - that is exotic genotype - did not send their cattle to pasture because of heat stress, while others, keeping from little to also highly specialised herds, did. Interestingly, no dairy production system was exclusively limited to the inner-urban areas; rather a semi-intensive dairy production-mixed herd composition, no animal in- and out-flow, pasture use but no own forage production - was common to both urban and rural areas, while semi- to highly intensive production systems were limited to rural areas.

**Keywords:** Cluster analysis, dairy production system, farm classification, India, rural-urban interface, urbanisation



## The Role of Crossbreed Cow Adoption on Farm Productivity and Technical Efficiency in Ethiopia

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Ethiopia has an enormous potential for milk production given its estimated 59.5 million cattle heads and 11.8 million cows. Over 98 % of the cattle are indigenous East African breeds characterised by low milk yield. Crossing of indigenous breeds with European breeds and promoting adoptions became the foci of Ethiopia's livestock development initiatives in the last fifty years. The initiatives were aimed at raising milk production and hence farmers' incomes. However, the effect of crossbreed cow adoption on the farmers' milk production performance remained unclear. This study examined the effect of crossbred cow ownership on productivity and technical efficiency in milk production. The study is based on a cross-sectional data collected from a stratified random sample of 250 farmers in three districts in central Ethiopia. Advances in productivity analysis uncovered the inadequacy of single-technology frontier methods in comparing the relative performances of decision makers which use heterogeneous technology. Such heterogeneity calls for a differentiated picture of potentials. In this study, we implemented two variants of meta-frontier production function framework: semi-parametric and fully-parametric methods. The results showed that the production frontier pertaining to farmers using only crossbreed cows is superior to those using only indigenous cows and those keeping both types. Farmers keeping only indigenous cows have the lowest production frontier. Mean technical efficiencies from a common meta-technology frontier are 0.76, 0.61 and 0.65 for only cross-breed cows group, only indigenous cows group and both types of cows group, respectively, under the semi-parametric method. We obtained rather lower mean technical efficiency levels of 0.72, 0.46 and 0.54 for the respective groups when the fully-parametric method is used. The results from the fully-parametric method are preferred for policy purposes since the method helps to address some obvious measurement issues in developing country data. The technical efficiency variations of the three groups signify enhanced effort and motivation for maximisation in high stake investments such as crossbreed cows compared to subsistence. The results suggest that the adoption of crossbreed cows helps to raise productivity, technical efficiency and market orientation. Nonetheless, further study is needed to identify constraints and drivers of the adoption.

**Keywords:** Crossbred cow, Ethiopia, meta-frontier, milk, productivity, technical efficiency

## First Serosurvey of Peste des Petits Ruminants, Rift Valley Fever and Brucellosis in Tiris-Zemmour Region, Mauritania

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The Tiris-Zemmour Region, in the North of Mauritania, is one of the less investigated areas of the country in terms of animal health even if it is epidemiologically interesting due to high animal presence mainly related to seasonal transhumance movements.

The aim of this study was to investigate the seroprevalence of Peste des Petits Ruminants (PPR), Rift Valley Fever (RVF) and Brucellosis in sheep, goats and camels in this region. Even if the first two were already reported in Mauritania, no data are available for the north of the country whereas Brucellosis was absent since 2014.

From September 2016 to February 2017, 916 blood samples (229, 277 and 410 from sheep, goats and camels, respectively) were collected in the departments of Zouérat, F'derick and Bir Moghreïn. Frozen sera were sent to the National Centre of Animal Researches of Nouakchott, for laboratory analyses. Presence of PPR antibodies were investigated using the ELISA kit ID Screen® PPR Competition (IDVet); IgG antibodies against RVF Virus were tested by the ELISA ID Screen®RVF Competition Multi-species (IDVet) and Rosa Bengal Test (RBT) was used to reveal *B. abortus* presence. Sixty-seven out of 158 sheep (42.4%; 95% CI: 34.6%-50.5%) and 88/232 goats (37.9%; 95% CI: 31.7%-44.5%) tested positive to PPR while all camels resulted negative. The seroprevalence of RVF IgG was 7.7% for goats (95% CI: 3.6%-14.1%) and 11.8% for camels (95% CI: 6.4%-19.4%). None of tested sheep was positive.

Regarding Brucellosis, all samples resulted negative in all species investigated. This study reveals a PPR seroprevalence in line with previous studies performed in Mauritania. This data could be overestimated since this country has taken part of the global eradication programme of PPR which also include animal vaccination and this test is not able to differentiate between infected and vaccinated ones. The only RVFV IgG presence indicate a previous contact with the virus, but not an active infection. Finally, the absence of *B. abortus* was confirmed. This study shows the importance to keep on monitoring health status of animals in Tiris-Zemmour since animal transhumance South-to-North could increase infectious diseases presence raising concern for both human and animal health, also considering some of them are zoonosis.

**Keywords:** Brucellosis, peste des petits ruminants, Rift Valley fever, seroprevalence

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## Effects of Tropical Legume Hays on Intake and Average Daily Gain of Ruminants: A Quantitative Review

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Several studies have been conducted to evaluate the effects of feeding tropical legume hays to ruminants, highlighting an advantage over feeding tropical grass hays. However, the results of most of these studies are confounded by an increased crude protein (CP) supply associated with replacing grasses by legumes. It is therefore difficult to assess the effects of feeding tropical legume hays exclusive from the changes in CP in the diet. Thus, a quantitative review was performed with the aim of collecting information concerning the nutritive value of diets containing tropical legume hays and the corresponding animal responses. The studies were attained through systematic web searches (i.e. Scopus, Google Scholar, Scielo), it had to be conducted under tropical or subtropical environments and had to include information on the proportion of legume in diets and the diet composition. A database with 233 studies (111 with sheep, 75 with goats, and 47 with cattle) consisted of 1083 dietary treatments including legumes and 207 diets without legumes were found reporting results on 97 legumes species. The most common tropical legume hays tested were *Leucaena leucocephala*, *Gliricidia sepium*, *Sesbania sesban*, *Calliandra calothyrsus*, and *Stylosanthes guianensis*. The most common ranges at which tropical legume hays were included in animal diets were 100–300 g kg<sup>-1</sup> dry matter (DM; 39 % of treatments), followed by 300–500 g kg<sup>-1</sup> DM (28 % of treatments).

Diets with legumes had higher CP concentration than diets without legumes for all ruminant species (average±standard deviation; 127±53.4, 139±48.1, and 171±152.5 g kg<sup>-1</sup>DM vs. 97±63.1, 103±54.1, and 139±114.7 g kg<sup>-1</sup> DM for sheep, goats, and cattle, respectively). Daily DM intake was also greater in diets with legumes than diets without legumes (69±17.0, 115±164.1, and 93±30.0 g kg<sup>-1</sup> bodyweight<sup>0.75</sup> vs. 56±17.1, 54±18.1, and 86±33.6 g kg<sup>-1</sup> bodyweight<sup>0.75</sup> for sheep, goats, and cattle, respectively). Similarly, average daily gain (ADG) was higher in diets with legumes than diets without legumes (98±178.7, 53±32.4, and 358±263 g day<sup>-1</sup> vs. 54±57.2, 26±26.9, and 278±225.8 g day<sup>-1</sup> for sheep, goats, and cattle, respectively).

Substituting tropical grasses by tropical legume hays increases ADG in corresponding animals. However, this is associated with an increased DMI mediated by higher dietary CP concentration and therefore intakes.

**Keywords:** Chemical composition, ruminants, tropical grasses, tropical legume hays

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## Estimation of CNCPS Protein Fractions from Proximate Nutrient and Fibre Concentrations in Tropical Ruminant Forages

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The fractionation of feed crude protein (CP) according to the Cornell Net Carbohydrate and Protein System (CNCPS) has proven to be a reliable method for estimating rumen CP degradability and thus duodenal flow of undegraded feed CP. However, concentrations of CP fractions are highly variable amongst and within forage species. Moreover, analysis of CP fractions is cost-, labor-, and knowledge-intensive. Thus, the aim was to evaluate whether contents of CP fractions in tropical forages can be accurately predicted from their proximate nutrient and fibre concentrations. A dataset on concentrations ( $\text{g kg}^{-1}$  dry matter (DM)) of CP, neutral detergent fibre (NDF), acid detergent fibre (ADF), and CP fractions (i.e., A, B1, B2, B3, and C) of 23 tropical forage grasses and 24 tropical forage legumes were used. Multiple linear regression analysis with backward elimination was performed to estimate concentrations of CP fractions from CP, NDF, and ADF. Mean ( $\pm$ standard deviation) concentrations of CP, NDF, and ADF of forage grasses were  $95.4 \pm 37.4$ ,  $617 \pm 79$  and  $384 \pm 73 \text{ g kg}^{-1}$  DM and  $178 \pm 30$ ,  $476 \pm 80$  and  $368 \pm 80 \text{ g kg}^{-1}$  DM for forage legumes, respectively. The CP and NDF concentrations were good predictors of the concentration of CP fraction A for forage grasses ( $R^2=0.82$ ), whereas for forage legumes, a more accurate prediction was obtained when ADF was additionally included ( $R^2=0.67$ ). Concentration of CP fraction B1 could not be predicted from CP, NDF, and ADF concentrations ( $R^2=0.08$ ). Variation in concentration of CP fraction B2 was well explained using CP, NDF, and ADF ( $R^2=0.83$ ). Similarly, for forage grasses, concentration of CP fraction B3 could be predicted from CP and NDF concentrations with acceptable accuracy ( $R^2=0.78$ ), whereas for forage legumes, NDF, ADF, and fraction B1 were better predictors ( $R^2=0.66$ ). For the CP fraction C in forage grasses and legumes, CP and ADF had a low explanation ( $R^2=0.40$ ). In conclusion, concentrations of CP fractions A, B2, and B3 can be predicted from CP and fibre concentrations in tropical forages; however, analysis of fractions B1 and/or C appears necessary.

**Keywords:** CNCPS, fibre concentrations, protein fractions

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## Beef Cattle Production in Brazilian Integrated Systems

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In Brazil, an estimated 11.5 million hectares are used for integrated systems, as crop-livestock (ICL), crop-forestry (ICF), livestock-forestry (ILF), or crop-livestock-forestry (ICLF). Even though the inclusion of trees in crop-livestock systems has been done for many years, a systematic evaluation of the effects of this association is still to be made. Therefore, we evaluated the effect of tree density on the productive performance of Nellore heifers in ICLF in the Brazilian Cerrado compared with conditions where no trees are included. Three systems, implemented in 2008, were evaluated, an ICL system and two ICLF systems, both with *Eucalyptus urograndis* trees (ca. 25m height) planted in single rows with 2 m between trees within rows and 14 m (ICLF14) or 22 m (ICLF22) between rows. The experiment lasted between June 2015 and May 2016 with randomized blocks, in split-block, with four replicates. The grass was *Brachiaria brizantha* cv. BRS Piatã and continuously grazed with variable stocking densities. A total of 48 heifers, 290 kg of initial liveweight, were randomly allocated in the systems, they were weighed monthly following 16 hours of fasting. The results were grouped per season (i.e., winter, spring, summer, autumn), and subjected to analyses of variance and Tukey tests at 5 % probability level. Annual stocking rate was higher ( $P < 0.05$ ) in ICL (1.9 animal units (AU) ha<sup>-1</sup>; AU=450 kg liveweight) compared to ICLF22 (1.1 AU ha<sup>-1</sup>) and ICLF14 (0.7 AU ha<sup>-1</sup>). Because of a lack of forage due to the high shading imposed by the trees, all animals in ICLF22 had to be removed in spring, whereas for ICLF14 all animals were removed both in spring and winter. Daily liveweight gain of individual animals did not differ between systems ( $P > 0.05$ ), averaging 0.673 g d<sup>-1</sup> in summer, 0.349 g d<sup>-1</sup> in autumn, 0.109 g d<sup>-1</sup> in winter, and 0.525 g d<sup>-1</sup> in spring. However, due to the higher stocking rate, ICL allowed for highest ( $P < 0.05$ ) annual liveweight gain per unit of land area (376 kg ha<sup>-1</sup>) followed by ICLF22 (229 kg ha<sup>-1</sup>) and ICLF14 (119 kg ha<sup>-1</sup>). The ICLF systems have lowest animal output per area; however, the overall benefits for farmers should also be considered income from the sale of trees.

**Keywords:** Animal production, eucalyptus, Nellore, silvopastoral, tropical grass

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## Animal Husbandry as a Strategy for Income Diversification of Small Vanilla Producers in the Sava Region of Madagascar

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This study, conducted in the main vanilla-growing Sava region in northeastern Madagascar, investigated the role of animal husbandry for income diversification of small-scale vanilla producers. The Sava region covers four districts with different characteristics regarding agriculture and animal husbandry practices. Individual interviews of 300 household heads were conducted between May and August 2017 to collect data on livestock ownership, management and marketing.

Across the study region, 84.4 % of the households practice animal husbandry. Median stock sizes were quite homogenous, with 3.5 zebus per zebu-keeping household, 2 pigs per pig-keeping household, 22 chicken per chicken-keeping household and 5.5 ducks per duck-keeping household. Throughout the four districts, the frequencies of vanilla-producing households (83 %), zebu-keeping (42 %), pig-keeping (13 %) and chicken-keeping (72 %) households as well as households keeping other poultry (22 %) were quite similar. There was a moderate correlation between vanilla production and animal husbandry in general (Pearson correlation,  $r=0.356$ ;  $p < 0.01$ ), chicken keeping ( $r=0.324$ ;  $p < 0.05$ ) and keeping of other poultry ( $r=0.331$ ;  $p < 0.01$ ), whereas no correlation existed between vanilla production and zebu-keeping as well as pig-keeping.

Animal products were sold at 0.90 € per litre of zebu milk, 4.70 € per kilogram of zebu meat, 2.90 € per kg of pork and 0.30 € per duck egg. Buying, fattening and reselling an animal yielded a plus of 9 % relative to the purchasing price in the case of zebu cattle, and of 275 % for a pig. For chicken and ducks, the respective values were 33 % and 267 %. By relating the gross margin to the average annual income of a vanilla-producing household, a potential income contribution of 1.3 % for a purchased and resold zebu and of 18.4 % for a zebu sold from own offspring was calculated. In the case of pigs, the potential income contribution was 3.3 % (purchased) and 4.5 % (offspring), and in the case of chicken and ducks the respective values were all lower than 0.5 %. In conclusion, the widespread small-scale livestock keeping of vanilla producing households seems to serve as an income buffering and diversification strategy, especially if the currently very high vanilla prices are decreasing again.

**Keywords:** Income diversification, northeastern Madagascar, small-scale livestock keeping, vanilla farming

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## Evaluation of some Economics Traits in Eastern Sudan Cattle Ecotypes

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Sufficient phenotypic variation in livestock populations is necessary for continual genetic improvement of economically important traits. The general aim of a livestock genetic improvement strategy is to produce a new generation of animals that better performs than the present generation. In eastern Sudan, cattle are mainly kept in a mixed crop-livestock production system and they play multifunctional roles in this system. A study was undertaken on (n = 1650) indigenous cattle ecotypes maintained under farmer management system in eastern Sudan. A total of 211 cattle households were randomly selected and interviewed with structured questionnaires to obtain information on some economically important traits (total milk production, age at first calving, lactation length, calving interval and longevity). Further information was obtained to quantify differences among eastern Sudan cattle ecotypes (Butana, Erashy and El-gash) under their natural production environment based on phenotypic markers. Data were analysed using General Linear Model (GLM) procedures when the economically important studied traits were selected as response variables and cattle ecotypes as fixed factors (main effects) to determine if there are significant differences in the responses across levels (fixed effect). It was found that all the studied traits were statistically significant ( $P \leq 0.05$ ) by cattle ecotypes. The overall means reported for total milk production (litters /season), age at first calving (months), lactation length (months), calving interval (months) and longevity (years) were  $1343.7 \pm 20.32$ ,  $48.2 \pm 0.13$ ,  $6.7 \pm 0.98$ ,  $17.8 \pm 0.11$  and  $17.8 \pm 0.36$ , respectively.

The differences between the studied economically important traits regarding indigenous cattle ecotypes are a key to improving cattle performance. By evaluating these traits, selection focus can be narrowed, resulting in faster genetic improvement. In the end, the goal of focusing selection on economically important traits as a tool is to increase probability that the breeders will make selection decisions on these traits that make the bred animals profitable.

**Keywords:** Cattle, economically important traits, evaluation, households, selection, Sudan

## Mapping the Suitability of Tropical Forages – Now and in the Future

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Livestock makes multiple contributions to the economic and social wellbeing of more than a billion livestock keepers across the globe: it provides income and highly nutritious food, it plays an important social role and is an asset for financial insurance. It also contributes to environmental resilience and sustainability through providing soil health and energy and in some cases protecting biodiversity. Key environmental footprints of concern, however, include nutrient loads, food-feed competition, GHG emissions, water use, and land-use conversion. Due to rising demand for livestock products, livestock's pressure on land and other resources continues to grow. It is thus imperative for the livestock sector to support a process of sustainable intensification. Improved forages and feeding strategies have been identified as one of the most promising entry-points for simultaneously enhancing livestock productivity and eco-efficiency.

In the face of climate change and its expected negative impacts on livestock systems, adaptation and increasing the resilience of livestock production systems should equally be a priority. Regions identified as the most vulnerable to climate change, such as Sub-Saharan Africa and South Asia, are also regions where farmers and rural communities rely the most on livestock for food, income and livelihoods, and where livestock is expected to contribute increasingly to food security and better nutrition. Arguably the most important climate change impacts are those mediated through the climate's impact on what the animals eat.

This paper describes the application of a suitability mapping tool to the case of tropical forages. The GIS tool is web-based, well documented and easy to use. It is packaged together with a spatial database and ideal for use by students, educators and development practitioners. Suitability maps for a wide array of tropical forages were produced, using both current and potential future climate conditions. Smallholder dairy farmers in Kenya, Tanzania, Rwanda and Ethiopia used these maps for selecting context-specific no-regret forage species and varieties. The maps also point to the gaps and opportunities for improving and expanding the choice of adapted forage options. This can, finally, be translated into breeding objectives for forage breeding programs.

**Keywords:** Eco-efficiency, forages, GIS, suitability

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## ***Ex-Ante* Evaluation of the Economic Impact of Adopting Improved Forages in the Colombian Eastern Plains**

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Forage-based cattle systems play a key role in rural economies of developing countries in terms of food security and poverty alleviation. However, they are often related to being a major cause of negative environmental impacts by contributing to increased greenhouse gas (GHG) emissions, land degradation, and reduction of biodiversity. As a result of that, large amounts of resources have been allocated to research and development (R&D) in forage material improvement and a broad range of improved materials were released showing superior characteristics in terms of productivity and environmental impacts compared to native or naturalized materials. However, data are still scarce on both the economic and environmental “yields” of investments in R&D activities around improved forage materials. Through an *ex-ante* evaluation, this study aims at estimating the potential “yields” of the investment in R&D and diffusion activities of the improved forage variety *Brachiaria brizantha* 26124 and the forage hybrid *Brachiaria* Cayman in the Eastern Plains region of Colombia. The analysis used two evaluation methodologies: a) to determine the impact on individual welfare, a discounted free cash flow model and a Monte Carlo simulation were carried out with the simulation software @Risk, and b) to determine the potential social benefits of the technologies and their distribution among producers and consumers, an economic surplus model was developed and a risk analysis was carried out considering changes in adoption rates, productivity levels and probability of success. Data is currently being analysed but preliminary results suggest that both evaluated materials present important economic benefits for the study region and result in a positive return on the investments made in R&D activities. The results will be a key input for decision making processes among public and private institutions involved in funding and executing the development of improved forage materials and will help to set research priorities and resource allocation.

**Keywords:** Agricultural research, decision making, economic surplus model, funding allocation, priority setting, technological change

## Colombian Cattle Producers' Preferences for Improved Forage Technologies: Chances for Forage Breeding and Selection

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The offer of improved forages in Colombia is characterized by its broad diversity. However, the adoption of improved materials is still very low despite numerous ecological and economic benefits for the cattle producers. This has led to various studies aiming at identifying the natural, social and cultural reasons inhibiting the adoption process. Some of these are that: a) innovations might have negative social connotations or create new problems for end-users; b) innovations might perform differently in different regions; c) traditional practices might be equal or better; d) extension programs might not be aligned with innovations or target the wrong population; and e) innovations might be too costly. From this perspective, participatory research methods can contribute to adoption by identifying experiences, demand, preferences and socio-economic characteristics of potential adopters and their farms and feeding this information back into the development of new innovations. This study has the aim to identify the preferences and demand of Colombian cattle producers for improved forage materials. During 2017, a total of 500 semi-structured interviews were conducted with cattle producers from the Caribbean (n=390) and Orinoquia (n=110) regions in Colombia. It was possible to identify an increasing concern among the producers about the impacts of climate change leading to a demand for more drought-tolerant forage materials with high nutritional quality. For producers from the Caribbean region, materials that help to increase milk production in double-purpose cattle systems are more important than for producers from the Orinoquia region. In turn, resistance to biotic stresses (Spittlebug) plays a crucial role for the Orinoquia region. In general, producers seem to be satisfied with most of the existing materials. This might be an obstacle for the adoption of new materials, i.e. if they do not differ too much from the existing ones. The findings are an important input for national and international forage selection and breeding programs and will provide a basis for decision making on where to set future priorities and how to allocate research and development funds. This, in the long run, will contribute to the development of materials that take into account the preferences and demand coming from the end-users and thus contribute to a faster adoption.

**Keywords:** Cattle production, forage breeding, improved forages, participatory research

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# Non-ruminant livestock and aquaculture

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## Anthelmintic Efficacy of Methanol Extract of *Momordica charantia* on Helminth of Nigerian Indigenous Chicken

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The anthelmintic efficacy of methanol extracts from the whole plant of *Momordica charantia* and bark of *Adansonia digitata* were compared and examined on *Ascaridia galli* of indigenous chicken of Nigeria. Phytochemical screening conducted on both extracts revealed the presence of steroids, alkaloids, saponins and tannins with an inclusion of flavonoids in *M. charantia* only. Three concentration levels of the extracts (0.25, 0.50 and 1.00 mg ml<sup>-1</sup>) and a control (0.00 mg ml<sup>-1</sup>) were prepared and tested on the larvae at 1:1 v/v. The treated L3 were viewed under an optical microscope for 120 minutes. The numbers of the motile worms were recorded after every observation. *In vivo* test of the most potent plant extract from the *in vitro* assessment was performed. Faecal samples were collected from 100 infested indigenous birds to confirm the presence of eggs and L3 of helminths. Doses of 400, 200 and 100 mg kg<sup>-1</sup> b.w. of the extract were used to treat the birds in Groups A-C. Groups D was the positive control (treated with Piperazine®) while birds in group E were left untreated as the negative control. Results from the *in vitro* tests presented in graphs revealed that 1.00 mg ml<sup>-1</sup> of *M. charantia* rendered all L3 immobile after 60 minutes, making it the most effective of both extracts. 1.00 mg ml<sup>-1</sup> of *A. digitata* achieved the same at 120 minutes. *M. charantia* was used in the *in vivo* test. After therapy, egg count was significantly higher ( $p < 0.05$ ) in Group E while that of Group A was significantly lower ( $p < 0.05$ ) than the other groups. In conclusion, the study shows that methanol extracts of both plants exhibited dose dependent anthelmintic activity in indigenous chickens and they are promising to be employed for the treatment of helminth infestation as an alternative to conventional anthelmintic chemotherapy by poultry farmers.

**Keywords:** *Adansonia digitata*, anthelmintic, *in vitro*, *in vivo*, indigenous chickens, *Momordica charantia*, phytochemical

## Does the Loss of Homestead Fish Ponds in Bangladesh Increase Food and Nutrition Insecurity of Poor Consumers?

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Fish is a vital component of food and nutrition security in Bangladesh. With the decline in capture fisheries, small scale aquaculture with home based fish ponds has been for a long time food safety net for the poor. Although producing small quantities, only for own consumption availability of fish made the poor less vulnerable to fluctuations in fish supply and prices. However, recently government has been discouraging home based small scale fish farming and promoted commercial fish farming instead. This paper analyses the transition from home based fish ponds to commercial aquaculture. Using two waves of panel data covering five major geographical hubs in Bangladesh, a double-hurdle model is estimated to examine the commercial transformation of non-commercial fish farmers and its implication for livelihood and household food and nutrition security. A correlated random effect procedure with a control function approach is used to control for unobserved heterogeneity and potential endogeneity of explanatory variables. Our results reveal that households are characterised with moderate degree of market participation. The average share of sold fish is 47 % of their total fish production with an increase of 19 % sold overtime. Market participation increases household income and generates a positive impact on their welfare. Almost 44 % of the farmers are subsistence farmers, whereas transitory and commercial farmers constituted 33 % and 23 % respectively. Overall, 50 % of the farmers change their degree of commercialisation over time and become more market oriented. The actual production depends highly on carp species with lower nutritional quality than small indigenous species, which are rich in micronutrients. Besides, commercialisation process of smallholders involved new risks with substantial transition challenges associated with price declines, production failures and investment risks. Therefore, smallholders need to receive positive support to face these challenges of commercialisation process for ensuring food and nutrition security at the household level.

**Keywords:** Aquaculture, Bangladesh, commercialisation, developing countries, food security, smallholders

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## Implementation of New Hatchery Technologies to Improve the Supply of Chambo (*Oreochromis karongae*) Fingerlings for Rural Farmers in Malawi

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Malawi has significant shares of the ninth largest lake in the world and the third largest and second deepest lake in Africa, which accounts for a traditionally fish-eating nation. However, overfishing resulted in the collapse of the Tilapia fishery in the lake since the beginning of the 90s. The historical yields of 70 % of Chambo (*Oreochromis karongae*) in the nets has turned into only 3–5 % Chambo today, with Usipa (Lake Malawi sardine, *Engraulicypris sardella*) being the most prominent fish in the catches from Lake Malawi providing at present 70 % of the yield.

Under these circumstances, aquaculture is being considered as one of the measures to provide more Chambo on the table and for the market, however, the production in the country is still small and in general not efficient.

Aquaculture has a tradition of about 100 years in Malawi, taking off with about 60 ponds in the 1950s and is represented today with about 6000 active fish farmers. Increasing production of Chambo could compensate for the decreasing yield from lake Malawi. At present, about 3600 t of Tilapia-like species are being produced, whereas 50 % of this yield comes yet from the only professional farm in Malawi, Maldeco Fisheries. One of the bottlenecks for rural farmers to improve their yield is the scarcity of sufficient viable fingerlings, specifically from Chambo.

Thus, one of the major goals of the project “Ich liebe Fisch” was to establish technologies which improve significantly the stable supply of viable fingerlings to farmers which want to grow fish for food and for the market. To achieve this goal, the project has provided a solar powered hatchery which is designed to support intensive production of Chambo offsprings.

The prototype of the hatchery was set up in March and April within about 3 weeks at the farm of the Bunda College in Lilongwe (Lilongwe University of Agriculture & Natural Resources, Department of Aquaculture and Fisheries) which plays an important role in providing training sessions for these new technologies. The presentation will introduce the applied technologies and will report about the implementation of this approach for mass production of fingerlings.

**Keywords:** Aquaculture, Bunda college, Chambo, fingerlings, fishery, hatchery, Malawi, *Oreochromis karongae*, solar power, tilapia

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## Characterisation of Small-Scale Commercial Poultry Sector in Western Kenya

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Poultry production can enhance the livelihoods of rural people. Poultry production in low and middle-income countries is dominated by small-scale backyard systems with low inputs and low outputs. Poultry production, productivity and generated income can be enhanced through intensification; the provision of inputs such as improved breeds, feed, housing and health-care. In Kenya, poultry production systems encompass free-range, semi-intensive and intensive systems. Despite a growing intensive sector, mostly located in and around Nairobi and other cities, indigenous chickens still dominate poultry production. However, their productivity could be improved in semi-intensive and intensive systems. Intensification is a relatively recent process in low- and middle-income countries compared to high-income countries. The complex reality of smallholders trying to improve their production is poorly understood and described. We explored the commercial chicken sector in a rural area distant from major production centres, and developed a fine-scale typology of commercial farms in western Kenya. We surveyed 111 chicken commercial farms in 2016. We targeted farms who sell the majority of their production, with 50 chickens or more, and in which animals were at least partly confined and were provided feeds. Farms were found mainly to raise dual-purpose indigenous chickens in association with crop production and were not specialised towards any particular product or market. Although the farmers interviewed shared many features of free-range system, they expressed the wish to make a commercial activity of their chicken production, with large flocks and management similar to semi-intensive farms. Four types of farms were identified based on two groups of variables, related to intensification and accessibility; (i) remote, small-scale old farms, with small flocks, using a lot of their own crops as feed, (ii) medium-scale, old farms with a larger flock and well located (iii) large-scale young farms, with large flocks, (iii-a) well located and who buy their chicks and (iii-b) remotely located and who hatch their chicks. These groups sit along a gradient of intensification. Location, which affects access to markets and inputs, determines the opportunities available to farmers and thus gives rise to further diversity in farm management types. We found that commercial chicken farms in western Kenya varied greatly in terms of management, opportunities and challenges.

**Keywords:** Farm typology, livestock intensification, poultry production

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## Feeding Response of African Giant Land Snail Fed Varying Levels of Ripe Eggplant Fruits Based Diets

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An experiment was conducted to evaluate the performance of growing African giant land snails (*Archachatina marginata*) fed diets containing varying levels of ripe eggplant fruit (*Solanum aethiopicum*). Eighty four juvenile (four months old) snails were randomly divided into four treatments (21 snails each) and three replicates per treatment (7 snails each) in a completely randomized design (CRD). The treatments were assigned to one of four caloric (2.78 - 3.13 Mcal kg<sup>-1</sup> ME) and nitrogenous (23.82 - 24.05 % crude protein, CP) diets containing 0, 5, 10, and 15 % of ripe eggplant fruits, respectively. Feed and water were offered *ad libitum* to the snails throughout the 12 weeks experimental period. Data were collected on growth performance (feed intake, body weight gain, shell length and circumference) and lipid profile. The results obtained showed no significant differences ( $p > 0.05$ ) among treatments in the growth performance, low density lipoprotein and triglycerides of snails fed diets containing varying levels of ripe eggplant fruits. Total cholesterol decreased and high density lipoprotein increased significantly ( $p < 0.05$ ) as the level of ripe eggplant fruits increased. Most consumers are scared of the cholesterol content of meat. The low cholesterol content of the snail fed with ripe egg plant fruit will make the meat from snail attractive to consumers especially the aged who are scared of cholesterol related illness. The addition of ripe eggplant fruits in the diets of *Archachatina marginata* in this study increased the high density lipoprotein of snail meat. High density lipoprotein is the 'good' type of cholesterol. It helps to remove excess cholesterol from the bloodstream and returns it to the liver where it is broken down and passed out of the body.

**Keywords:** Feeding, growth performance, processing

## **Influence of Crop Residues as Major Fibre Sources in Diets on Growth Indices of Rabbits**

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Crop residues are a sustainable feed resource for livestock production in Nigeria. Incorporation of fibre in the diets improves the nutrition and gut health of rabbits. Corn cob, rice straw, groundnut and cowpea stovers, millet straw, sugarcane tops are a few of the available crop residues in Nigeria. In a study, conventional maize offal (MO) was replaced by corn cob (CC) and rice straw (RS) as fibre sources in the diets of growing rabbits. Eighty four growing rabbit bucks of New Zealand White  $\times$  Chinchilla crosses weighing  $746 \pm 2.3$ g were randomly allocated to seven dietary treatments, with twelve rabbits per treatment at three replicates of four rabbits per replicate in a 56-day feeding trial. The experiment was laid as a completely randomised design in which corn cob and rice straw were each used to replace a proportion of the 30% MO in the control diet at three graded levels to have seven dietary treatments labelled: Control, 10 % CC, 20 % CC, 30 % CC, 10 % RS, 20 % RS and 30 % RS. All the diets were pelleted. Daily dry matter intake ( $64.5 \pm 0.4$  g day<sup>-1</sup>) of rabbits on 20% CC based diets was found to be significantly higher than the MO based control diet ( $59.0 \pm 2.4$  day<sup>-1</sup>). Feed cost per kilogram gain was lowest ( $P > 0.05$ ) on 20 % CC based diet (N515  $\pm$  60.9), against N612  $\pm$  155.1 for the control, while the highest feed cost per kilogram gain was found for the 30 % RS based diet (N763  $\pm$  183.9). There was significant difference in carcass weight for rabbits that consumed 20 % CC based diet (1629  $\pm$  161.6g) as compared to the rabbits fed 30 % RS based diet (1243  $\pm$  101.3g), but comparable to the control (1542  $\pm$  61.6g). Increasing levels of CC in the diet increased the length of small intestine of rabbits but a contrary observation was recorded for rabbits fed RS based diets. In conclusion, replacing the conventional maize offal with corn cob up to 67 % in the diet of growing rabbits was more economical, improved carcass weight, and did not compromise growth performance.

**Keywords:** Carcass characteristics, crop residue, growth performance, livestock production, rabbits

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## Cavy between Food Security and Conservation in Kahuzi Biega National Park, Sud-Kivu, DR Congo

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The Democratic Republic of Congo (DRC) in general and the province of Sud-Kivu in particular are facing serious problems of food and nutrition insecurity due to recurring wars, continued armed conflicts, and poor governance, resulting in low agricultural production. Kahuzi Biega National Park (PNKB) has become the major resource for local populations adjacent to it in order to achieve a certain food security. This includes game hunting, tree felling, and extraction of minerals, among others. However, it contradicts the main goals of the park in terms of nature conservation. To ensure the protection of this heritage of global interest, the Wildlife Conservation Society (WCS), the Union of Cavy Keepers in Congo (UECCO), the Congolese Institute for Nature Conservation (ICCN) and local communities have developed a project for cavy (*Cavia porcellus*) production.

The main objective of this project is to help communities around PNKB to increase cavy production through adequate housing, quality feed of sufficient quantity, controlled reproduction, and disease management. In addition, the communities receive training in culinary preparations and cavy marketing. Choosing cavies as an alternative for bushmeat consumption in the conservation strategy of PNKB is determined by the advantages that this small animal offers, such as being a strict herbivore, its high feed conversion ratio, the high growth rate and, especially, the significant levels of high-quality proteins in its meat as well as the low fat content. Cavy manure is also used as fertiliser and, thus, helps increase the production of market garden crops such as cabbage, onions, and potatoes. Vegetables grown with cavy manure are highly appreciated in the market.

Since its inception in 2016, the project has reached about 600 households with 150 families effectively involved. On average, beneficiary households keep 38 cavies, selling about 6 animals per month and consuming 3 per week. As so-called 'local champions', many cavy producers from the project area have become trainers in the region. Eventually in the eastern region of DRC, cavies have demonstrated to be a secure source of income and contribute to the empowerment of women, youth/children and former hunters.

**Keywords:** Bushmeat, food and nutrition security, guinea pig, income, nature conservation, protected area, women empowerment, youth participation

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## Village Chicken (*Gallus gallus domesticus*) Intensification and Production in South-South Nigeria for Food Security: The Role of Research

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The high cost of production of chicken in Nigeria has resulted in high prices and reduced its availability to a large majority of Nigerians thereby reducing food security in the country. The village chicken in Nigeria is a valuable resource that is threatened with extinction because of competition with the exotic breeds and subsequent neglect of the species by most farmers in Nigeria. This paper analyses the development and integration of the local village chicken into the production stream in Nigeria with a view to stem the tide of neglect and reduction in the population of the breed. The study used data collected from purposively selected respondents that keep village chicken and those that kept the exotic breeds as well as researchers on chicken in South-South Nigeria. Data collected were analysed using simple percentages, T-tests and rankings. The results show that the village chicken had a greater acceptance and preference for meat quality than the exotic breeds. It also had a wider range of preferred products with traditional, cultural and spiritual significance than the exotic breeds in Nigeria. The T-test results showed that there was a significant lower difference ( $p < 0.01$ ) in production cost of the village chicken than the exotic breed. Similarly, the resistance to disease and stress was higher in the village chicken than the exotic breed. There have been some genetic improvements in some village chicken through cross breeding that further improves village chicken preference. The study recommends the promotion of village chicken production to stem the extinction tide. Intensification and further genetic engineering through research is recommended to boost production and output characteristics of the village chicken. The village chicken still has a lot to contribute to the development and promotion of animal protein supply in Nigeria and poverty alleviation in Africa.

**Keywords:** Comparative analysis, exotic chicken, genetic engineering, intensification, production cost, village chicken

## Impact of an Organic Acid Blend on Feed Efficiency and Mortality of Broilers in Southern India – A Performance Analysis

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Overuse of antibiotics, the development of resistant bacteria and their damaging effects on human health have led to the ban on the prophylactic use of antibiotics in animal farming. However, looking at the bacterial challenges experienced in farming, it is still imperative to have a tool to control bacterial infection and improve performance of animals. Organic acids are considered the most promising alternative to the antibiotic growth promoters. In addition to their anti-bacterial and anti-fungal properties, organic acids provide many extra benefits such as improving overall feed hygiene, optimising the intestinal pH and thereby improving nutrient digestibility. Organic acids and their salts have been tested in poultry production since the 1980's. The current study investigated the impact of an organic acid blend (OAB), consisting of sodium propionate, propionic acid, ammonium formate, formic acid, as well as sorbic acid and a surfactant, developed and previously reported to improve feed hygiene, on its influence on broiler performance in commercial farms in southern India. This study analysed the average impact from all studies carried out in southern India on the effect of the additive on feed efficiency and mortality. The final data-set contained the results of 23 farm trials with 0.1 % OAB-inclusion and covered 224,000 broilers (Ven-cobb 500). Results are expressed as percentage difference from the negative control. Data were subjected to statistical analysis and a significance level of 0.05 was used in all tests. The performance of broilers based on feed efficiency was significantly improved by 2.8 % ( $p = 0.009$ ). Furthermore, mortality was significantly reduced on average by 14.3 % ( $p = 0.025$ ). This is in full agreement with previous reports on the impact of “feed hygiene enhancer” on broiler performance. It is therefore concluded that the OAB can, next to its beneficial effects on feed hygiene, also have a beneficial impact on broiler production under Indian conditions.

**Keywords:** Broiler performance, feed hygiene, India, liquid acid blend

## **Growth Performance, Carcass Characteristics, Haematological Indices and Apparent Nutrient Retention of Broiler Birds Fed Enzyme-Supplemented High Fibrous Diets**

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The objectives of this eight weeks study were to evaluate the growth performance, carcass characteristics, haematology and apparent nutrient retention of broiler birds fed Roxazyme G<sup>®</sup> enzyme supplemented high fibrous diets. Two hundred day-old Agrited broiler birds were divided into ten experimental treatment groups of 20 birds, with two replications of 10 birds each. The groups were randomly allocated to each of ten diets in a 5×2 factorial arrangement that involved a control (0% wheat offal without enzyme) diet, four levels (10, 15, 20, 25) of wheat offal, and two enzyme levels (0 and 0.02 %) at the starter phase, and a control diet, four levels (10, 20, 30 and 35 %) of wheat offal, and two enzyme levels (0 and 0.02 %) at the finisher phase. Average final body weight, average daily weight gain, feed conversion ratio, carcass and organ weights were not different ( $P > 0.05$ ) among dietary treatments. Significant ( $P < 0.05$ ) interactions were observed between wheat offal and enzyme levels in average daily feed intake (ADFI). Dietary enzyme reduced ( $P < 0.05$ ) average daily feed intake (ADFI) at all levels of wheat offal inclusion. White blood cell count (WBC), red blood cell count (RBC), haemoglobin concentration (Hb), lymphocytes, neutrophils, monocytes, basophils and eosinophil were not different ( $P > 0.05$ ) among treatments. Packed cell volume (PCV) varied considerably among wheat offal and enzyme treated birds. Observable ( $P < 0.05$ ) interactions occurred between dietary wheat offal and enzyme in PCV. Broilers that received 10, 30 and 35 % dietary wheat offal and enzyme had improved ( $P < 0.05$ ) PCV. Dietary wheat offal and supplementary enzyme significantly ( $P < 0.05$ ) affected apparent retentions of dry matter (DM) and ash. Significant interactions ( $P < 0.05$ ) occurred between dietary wheat offal and enzyme. Digestion of ash was markedly ( $P < 0.05$ ) increased by enzyme at all the levels in which wheat offal was included in the diet, whereas increase in DM retention occurred only at 20 % and 35 % wheat offal. The findings of the present study showed that broiler birds could tolerate up to 35 % inclusion level of wheat offal in their diets when supplemented with Roxazyme G<sup>®</sup> enzyme.

**Keywords:** By-products, enzyme, fibrous, retention, wheat offal

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## Assessment of the Efficacy of Bentonite-Montmorillonite Binder as Biosystemic Sequestering Agent at High Dietary Aflatoxin Load in Turkey Poults

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Aflatoxin is implicated in the aetiology of many diseases in poultry and turkey. The use of clay mineral has been reported to improve performance of broiler chickens during aflatoxicosis. However, information on the mitigation of aflatoxicosis in turkey using clay and yeast has not been adequately documented. Therefore, the use of Bentonite-montmorillonite binder (BB) to mitigate aflatoxicosis in turkey was investigated. Eighty 21-day old Nicholas turkey poults were randomly assigned to five treatments of four replicates with each replicate having four turkey poults. The experimental diets which were formulated to meet the standard dietary requirement of turkey poults were: positive control (PC) with no aflatoxin or BB, negative control (NC) with 0.2 mg kg<sup>-1</sup> of total aflatoxin, NC + 2 g kg<sup>-1</sup> BB, NC + 4 g kg<sup>-1</sup> BB and NC + 6 g kg<sup>-1</sup> BB. The experiment was observed for 21 days during which necessary poultry management practices were observed. Data on feed intake, body weight gain, feed conversion ratio and mortality were collected as performance indicators while 5ml blood samples were collected via jugular venopuncture for serum biochemical analysis. Aflatoxin significantly reduced feed intake and body weight gain in poults that were treated with aflatoxin and BB. Mortalities were 0 %, 56 %, 44 %, 56 % and 38 % for diets 1, 2, 3, 4 and 5, respectively. Serum protein and albumin were also reduced significantly in poults that received aflatoxin alone and with binder. In conclusion, there was no significant effect of inclusion of bentonite-montmorillonite binder up to 0.6 % on the response criteria measured in this study.

**Keywords:** Aflatoxicosis, bentonite-montmorillonite, turkey poults

## Awareness of Farmers and Traders on Newcastle Disease in Kenya

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Newcastle disease is the most prevalent chicken disease in Kenya. It accounts for over 80 % of chicken mortality rates thereby depriving farmers and traders of their source of income and livelihood. The disease is a main challenge for farmers who rear indigenous chicken under the free range production system. This is worsened by most farmers lacking information about the disease. In Kenya, there is limited information regarding farmers' awareness, outbreaks and socio-economic impacts of the disease on livelihoods. The current study aimed at assessing farmers' and traders' awareness on Newcastle disease. A focus group discussion (FGD) consisting of chicken farmers, traders and veterinary officers was conducted to get insights on the chicken value chain practices and new castle disease. A total of 311 respondents consisting of 192 chicken farmers in six sub-counties and 119 chicken traders in seven live bird markets were randomly interviewed. Awareness of new castle disease was demonstrated by the respondents' ability to present symptoms consistent with the clinical signs of the disease. Means, percentages, graphs and frequencies were used to present the findings. Results revealed that 64 % of chicken farmers were female while about 83 % of chicken traders were male. This shows that chicken production is a female dominated activity while chicken marketing is male dominated. Only about 20 % of farmers and 18 % of traders had received training on the disease. About 25 % and 23 % of farmers and traders had received credit access to institutional support through formal training and credit is crucial in helping farmers invest in proper preventive and management and practices. Awareness to Newcastle disease was high with about 85 % of the farmers and 78% of traders being aware of the disease. Results also reveal that approximately 78 % of the traders and 46 % of farmers had experienced outbreaks of the disease. Outbreaks of ND were higher among traders than farmers due to poor market infrastructure and lack of biosecurity measures. These findings showed that training about the disease is important to help increase awareness. There is need therefore to invest in improved biosecurity measures, good husbandry practice and proper hygiene and disease surveillance to prevent ND outbreaks and spread.

**Keywords:** Awareness, bio-security, Newcastle disease

## Identification of Management and Production Practices in Indigenous Pig Farms in North-West Vietnam via Multivariate Analyses

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Pig production systems using indigenous breeds have a substantial impact on diversity in Vietnamese pig populations and also contribute to the income of small-scale farms in the northwest of Vietnam. In order to characterise indigenous pig (Ban pig) production systems, single person interviews basing on semi-structured questionnaires were conducted between October 2016 and January 2017 in 171 indigenous pig farms. The Ban pig production systems were classified using i) a two-step clustering approach, and ii) K-means clustering combined with categorical principal components analyses (CatPCA). Two-step clustering allocated the farms into three clusters. The first cluster was called “Nursery farms with low disease incidences” because 96 % of these farms sold piglets to the slaughterhouse after the nursery with a live weight between 10 to 25 kg. A large percentage of farms in cluster 1 had absolutely healthy piglets and/ or sows (41 % and 51 % of farms, respectively). Cluster 2 was named “Fattening and mixed farms with high investment and high disease incidences” because these farms had large pigpen sizes (20.03m<sup>2</sup>), modern pigsty constructions, but a high rate of disease incidences. Similar to cluster 1, farms in cluster 3 also focused on the nursery phase, but the pigpen and herd size was smaller (12.13m<sup>2</sup> and 7.61 piglets respectively). Hence, cluster 3 was defined as “Nursery farms with low investment”. The K-means cluster after CatPCA classified farms into a cluster A “Farms incorporating male and female farmers in farm management”, cluster B “Nursery farms with low efficiency”, or cluster C “Farms with long weaning interval”. Correspondingly, husband and wife were herd managers in 64 % of farms in cluster A. Average weaning age for farms in cluster C was 70,25 days. We compared the farm allocations from both clustering approaches, and we identified substantial differences. In the last step, univariate analyses were applied, in order to identify factors contributing to the net household income from pig production. The vaccination for the sow, type of operation, number of piglets born alive, nursery weight, and nursery interval were the factors significantly affecting the net revenue in Ban pig production systems.

**Keywords:** Ban pig, cluster analysis, North-West Vietnam, production systems

## Genetic Heterogeneity of African Swine Fever Virus within the Sylvatic Cycle in Central Mozambique

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To determine if African swine fever (ASF) is maintained in a sylvatic cycle in Mozambican wildlife areas, we investigated the presence of soft tick reservoirs of ASFV and their infection rates in the Gorongosa National Park (GNP) and its surrounding villages. The GNP is one of the largest national parks located in the centre of the country. A total of 1,658 soft ticks were recovered from warhog burrows and pig-pens at the wildlife/livestock interface and viral DNA was detected by nested PCR in 19 % of *Ornithodoros porcinus porcinus* and 15 % of *O. p. domesticus*. Isolation of the virus was successful in approximately 50 % of the PCR-positive samples with nineteen haemadsorbing virus isolates recovered. These were genotyped using a combination of partial gene sequencing (p72, p30 and p54) and analysis of the central variable region (CVR) of the B602L gene. Eleven isolates clustered in genotype II and were homologous to contemporary isolates from southern Africa, the Indian Ocean and Eastern Europe. Three isolates grouped within genotype V were similar to previous isolates from Mozambique and Malawi. The remaining five isolates constituted a new, previously unidentified genotype, designated as genotype XXIV. The isolates classified within genotypes II and XXIV clustered into three major subtypes based on their p30 and p54 sequences. Based on analysis of the CVR gene, the viruses were classified into eight subgroups. This work corroborates for the first time the wildlife origin of Genotype II and confirms that a large diversity of ASFV strains maintained in wildlife areas can act as a permanent source of virus for the domestic pig value chain in Mozambique and beyond its boundaries. Their genetic similarity to ASFV strains currently spreading across Eastern Europe suggests that the African sylvatic cycle has a high potential to disseminate different ASFV into new geographic areas and justifies the need to continue studying the epidemiology and ecology of ASF sylvatic hosts in sub-Saharan Africa.

**Keywords:** African swine fever, genetic characterisation, Mozambique, *Ornithodoros moubata*, sylvatic cycle

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## **Assessment of Adaptation Strategies to Climate Change and Fish Farmers Production in South-West Nigeria**

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Fish is a major source of animal protein and it is a very important aspect of agriculture. Food security is when a household has physical and economic access to all classes of food stuff needed by every member of that household. Animal protein is needed by various categories of members of a household in various quantities. Talking about food security and safety, importance of fish as a source of animal protein cannot be over emphasized. Climate change is a major problem which has led to low fish production to fish farmers in the study area. Fish farmers must have developed some adaptation strategies to climate change challenge in the study area. The study was designed to examine the socio-economic characteristics of the fish farmers, identify various adaptation strategies to climate change by fish farmers, examine the perception of farmers to climate change and assess the productivity of fish farmers as a means of achieving food security in the study area. The study was carried out in the southwest region of Nigeria. A purposive sampling procedure was used to select Ondo and Ogun States and 160 respondents were purposively selected due to their involvement in fishing activities in the region. Data was analysed with descriptive and regression analyses. Male farmers dominate the respondents, most are single and majority are Christian. It was also revealed that main purposes of production are household consumption, commercial and as hobby. Most of them engage in both catfish and tilapia production. Result reveals that adaptation strategies employed by fish farmers in the study area are construction of barriers, improving water source and conservation of fish species. Moreover, regression analysis result showed significant relationships between educational level and productivity at 10% level of significance. It was recommended that government at all levels should give incentives and information on climate change and its adaptation strategies to fish farmers to enhance their production and thereby ascertain food security. Universities should make the results of their research available in form of technological package which should be made available to farmers through their extension service delivery to enhance food security.

**Keywords:** Adaptation strategies, climate change, productivity and food security

## **Farm to Food Security: An Impact Evaluation of Tilapia Researches under Thailand Research Fund**

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Agricultural research plays an important role in addressing and solving current problems of farm and food security. Tilapia has become the third most important aquaculture fish after carp and salmon worldwide and has been the most crucial fish species in Thailand mainly for food security. The evolution of Tilapia aquaculture certainly has derived from the investment in research and development. Thailand Research Fund (TRF) has been principally investing in Tilapia research for a long period of time. The study aims to evaluate the past investment in Tilapia research. Accordingly, the data collected from 33 Tilapia research projects under the TRF support are assessed. In addition, 8 case studies are selected and intensely evaluated. The five important OECD research evaluation criteria i.e. relevance, effectiveness, efficiency, impacts and sustainability, are employed in the study. The economic evaluation is performed by using the net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR). The results indicate that most Tilapia research met the OECD criteria on relevance and effectiveness. However, to come across with the efficiency and impact indicators, users and adoption must play an important role. The sustainability indicator seems to be the most critical issue while farmers dis-adopt technology quickly after the project ended. In conclusion, the past Tilapia research projects under TRF support were worthwhile invested with a NPV of 2.75 million Euros; a BCR of 6.74 and the IRR equals to 55 %. Thus, in order to extend the impacts from farm to global food security, future research on Tilapia should be targeted on users' adoption in order to initiate higher economic impacts throughout the value chain.

**Keywords:** Food security, impact evaluation, Thailand, Tilapia research

## **Vertical Integration in Fish Culture Business in Rivers State, Nigeria: Panacea for Food Security**

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The study examined vertical integration in fish culture business as panacea for food security in Rivers State, Nigeria. The characteristics and integrated activities of vertically integrated and non-vertically integrated fish culture farms were compared. The vertically integrated fish culture farms produce feeds, fingerlings and dry fish using smoking kiln, while the non-vertically integrated fish culture farms buy feeds and fingerlings from independent suppliers and dry fish using fire wood. Data for the study were obtained from 37 vertically integrated and 119 non-vertically integrated fish culture farms. Purposive sampling was used for the vertically integrated, while multi-stage sampling was used for the non-vertically integrated fish culture farms because of the availability of a farmer list. Data were analysed using descriptive statistics, budgetary and profitability indices. The farms differ amongst others in their mode of operation. The average cost of N11 and N19 was incurred per fingerling as well as N1,987 and N4,423 per bag of feed by the vertically integrated and non-vertically integrated fish culture farms, respectively. The average cost of N314 and N477 per kg of fish produced was incurred by vertically integrated and non-vertically integrated fish culture farms. The vertically integrated fish culture farms could sell fresh fish at N440 per kg and still make equal profit as the non-vertically integrated fish culture farms that sold fresh fish at N600 per kg. The vertically integrated fish culture farms processed fish at lower cost than the non-vertically integrated fish culture farms which make fresh fish economical and affordable, thus enhancing food security.

**Keywords:** Aquaculture, food security, Nigeria, panacea, vertical integration





# Pastoral systems

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## Pastoralism in Eastern Africa: Policy and Institutional Challenges, Opportunities and Responses

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Pastoralism is a major livelihood, production and land-use system in nine countries of Eastern Africa (Djibouti, Eritrea, Ethiopia, Kenya, Somalia, South Sudan, Sudan, Tanzania and Uganda). It is indeed the most appropriate land-use and production system for the extensive drylands that cover nearly 75 % of the region's landscape. About 90 % of the livestock population in the region is found in these drylands, making them an important part of the region's food and nutrition security and economic development. Moreover, pastoralists constitute significant proportions of national populations in these countries, ranging from 10 % in Kenya and Tanzania to 60 % in Somalia and South Sudan.

Yet the practice of pastoralism has historically been constrained by significant policy and institutional challenges. Since colonial times, governments in this region have perceived pastoralism as backward and inimical to the dictates of modernisation and economic transformation that privilege sedentary land-use and production systems and envision a livestock sector founded on intensive commercial production. Pastoralists have historically been marginalised from and by policy processes, not least because, save for Somalia and South Sudan, they constitute minorities in the countries of the region and live on the geographical margins of their countries, away from the centres of political and commercial power. In Somalia and South Sudan where pastoralists are the majority, conflict and insecurity have undermined political processes and opportunities for them to use their numbers to craft supportive policies and institutions.

Since the turn of the century, however, there have been promising policy and institutional developments at the regional level and within the different countries. These developments hold the promise of mainstreaming pastoralism into national economic development processes and thereby securing pastoral livelihoods. Even Somalia and South Sudan are involved in the regional policy and institutional development processes.

This presentation will highlight these developments, analyse the promise they hold for pastoralism, identify challenges that have still to be overcome for pastoralists to fully benefit from them, and makes recommendations on how stakeholders can contribute to strengthening the policy and institutional context for pastoralism in Eastern Africa.

**Keywords:** Eastern Africa, pastoralism

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## Is Fodder Production in the Drylands Profitable? Analysis of Fodder Value Chain in Southern Kenya

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Pasture scarcity is a major hindrance to livestock production among communities living in the drylands of Kenya. The situation is normally worsened by droughts which have become more severe and frequent in the drylands. This has led to increased livestock mortalities and weaker adaptive capacity of pastoral and agro-pastoral communities to climate variability and change. Fodder production and marketing have been embraced by pastoral and agro-pastoral communities in Kenya to enhance pasture availability for their herds and also to diversify households' sources of livelihood. This study was motivated by little empirical evidence on the adoption of fodder production, efficiency and profitability of fodder marketing among households in the drylands of southern Kenya, where various fodder production technologies have been widely promoted. The study was conducted through household and key informant interviews, as well as focus group discussions. The results indicated that the most adopted fodder production technologies were range reseeding and enclosing natural pastures to allow regeneration, which were adopted by 48 % and 36 % respectively. A large proportion (83 %) of those who adopted range reseeding were members of social groups. Hay and grass seed traders and Kenya Agricultural and Livestock Research Organisation were found to be the most influential actors in the fodder value chain in the study area. Profitability analysis indicated that hay and grass seed production is a profitable venture (cost benefit ratio of 1.73). However, market performance and efficiency analysis revealed low comparative profitability by the producers as traders buy seeds at low prices (\$2/kg) and sell mainly to NGOs at much higher prices (\$8/kg), while incurring less than one dollar in marketing. This could be attributed to the informal and unregulated nature of the fodder market, which gives the traders undue advantage over the producers. It is necessary that fodder markets are formalized and appropriate structures put in place to enhance market efficiencies and access to marketing information. This will open up alternative markets allowing producers to access better prices. This will support out-scaling of fodder production and its economic benefits thus enhancing adaptive capacity of pastoral and agro-pastoral communities to climate change

**Keywords:** Agro-pastoral, livestock, marketing, pastoral, technologies

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## One Health Approach: Key Function in Project Activities in Food Security and Safety in Somaliland

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Food security and safety are global priorities that need to be approached with a trans-disciplinary One Health concept. Vétérinaires sans Frontières Germany has implemented various projects in collaboration with local private and public stakeholders in East Africa for 27 years by applying an approach that is now gaining recognition as One Health approach, bringing together multiple disciplines to achieve health for people, animals and environment. In Somaliland, small amounts of animal source high-quality proteins and micronutrients are essential for growth and health of the population, whose demand is increasing. In this region, livestock related activities account for 60–70 % of the gross domestic product, employ 80 % of the workforce and contribute to the national economy and food security. Yet the market availability of local animal products is unreliable due to climate conditions, low production and quality, poor marketing conditions and inadequate regulatory systems in dairy and meat sector, among others. The aim of this project is to improve food security and living conditions by enhancing access of consumers to local quality animal protein and stabilising the livelihood of all members of the milk and meat value chain including producers, processors, vendors and Community Animal Health Workers (CAHWs). To accomplish this, a holistic approach has been implemented to promote the collaboration between all stakeholders. One of the key components of the project is capacity-building, in which the members of the milk and meat value chain, especially women, CAHWs and private veterinary drug suppliers received technical trainings and equipment. Another component covers construction and rehabilitation of basic infrastructures like markets. In addition, a capacity assessment and training of relevant stakeholders in the public sector was conducted, to identify deficits in the public health regulation frameworks and contribute to policy development and implementation. As a result of these activities, the quality of local animal source products has improved, hence increasing the income of producers, vendors and processors and the access of the population to hygienically improved animal protein. Moreover, the capacity to regulate and provide services by governmental institutions in the milk and meat sectors is enhanced ensuring quality and safety of food products.

**Keywords:** Food safety, milk and meat value chain, women empowerment

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## Linking Pastoralists to Markets – Understanding the Role and Working Conditions of Local Traders in Northern Kenya

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Livestock trade is the major source of income for pastoralists, traders, and other actors in pastoral meat value chains. Pastoralists in northern Kenya obtain income by selling sheep and goats through local long-distance traders who connect them to the Nairobi terminal market. However there is little information about the conditions under which traders perform the task of “linking pastoralists to markets”. The aim of this study was to understand how traders operate, their information needs and the profitability of their business. Based on 12 months of fieldwork conducted between 2014 and 2016, we assessed traders’ activities, the information exchange along the value chain and their business transactions to understand their costs and profits. A stakeholder analysis resulted in the identification of six categories of local traders distinguished by different demands in travel, labour, working capital, risk exposures and relations with other actors. Our analysis also revealed relational gaps that disadvantage local traders through a lack of information leading to low net profits, high operating costs and economic losses. Further analysis of information flow along the value chain revealed specific information needs of traders; such as the range of prices in different markets, the extent of competition, grades of animals in high demand and further animal specifications. Market information tended to change within a short time-span. As a result, the weekly prices for different grades showed high price variability such that prices were only known on the market day. These unpredictable prices contribute to fluctuating net-profits, low returns on capital investments, and high operating costs and economic losses, particularly for those local traders that sell at the terminal market (long distance traders). These multiple challenges make the long-distance trade precarious, hence the local traders struggle to offer better prices to pastoralist producers. This study shows the precarious situation of long-distance traders in the sheep and goat chain and highlights areas where relationships can be strengthened to improve coordination of activities, reduce operating costs and improve information flow so that the local traders can make better and timelier decisions to improve their margins.

**Keywords:** Activity links, actor network, goats, northern Kenya, pastoral livestock production, supply chain, traders

## Grassland Functions Improve a Mechanistic Crop Model to Assess Savannah Crop Encroachment and Overstocking Impacts

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In Ethiopian Borana rangelands, crop encroachment directly and indirectly influences savannah ecosystem functions. Plant cover is temporarily reduced and soil structure disturbed through tillage when pastures are converted to cropland. Indirectly, rangeland fragmentation inhibits traditional spatio-temporal herd mobility. Overstocking on the remaining continuously grazed pastures can cause rangeland degradation through declining surface cover and reduced soil organic matter formation. On poorly structured soils, intensification-induced soil organic matter loss diminishes water infiltration- and retention capacity. Reduced surface cover is main driver for soil erosion and vegetation degradation on sloping terrain. In summary, the vulnerability to degradation depends on soil characteristics and topography across a heterogeneous savannah landscape. Vegetation structure then regulates actual degradation, depending on pasture's capacity to recover from intensive grazing under certain site conditions.

We employ the mechanistic grid-based land use change impact assessment tool (LUCIA) to study the mechanisms described above. LUCIA's spatially explicit structure allows simulating crop encroachment and herd mobility patterns, which have not been described yet. We developed grassland functions and integrated them in a modular way into the LUCIA main program. Herd routes across the landscape follow patterns of pasture quality and availability, which govern intake and nutrient excretion. The grassland module adds functions to represent pasture plants' post-grazing rehabilitation capacities: (1) Short plants producing many side shoots retain more residual leaf area after grazing than erect morphotypes. (2) Preferential assimilate allocation to leaf-regrowth allows rapid canopy re-establishment. (3) Rejuvenation of foliage by investing in young leaves boosts regrowth through increased leaf area photosynthesis. (4) Enhanced nutrient demand to build young tissue can constrain regrowth. These functions regulate the impact of overgrazing on vegetation- and soil degradation.

By running scenarios, we can show that crop encroachment rate and the spatial distribution of cropping and overgrazing influence ecosystem processes, such as erosion, water retention, soil organic carbon storage and plant productivity. For future coupling of LUCIA with herd- and farmer's decision models, the grassland module functions as connection point.

We discuss process-representation improvements by implemented grassland functions and how model coupling is expected to enhance the understanding of major feedbacks within complex socio-ecological savannah systems.

**Keywords:** African savannah, ecosystem functions, land use change, pasture regrowth, spatially explicit modelling

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## Model-Based Assessment of Grazing Impact on Soil Carbon Stocks and Dynamics of a Kenyan Rangeland

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Significant increase in atmospheric carbon concentration is a major driver of global warming and climate change. As the largest terrestrial ecosystem carbon sink, soils store approximately 2500 Pg. C in the upper 2 m depth. Rangelands make up more than 40 % of the global land surface and contain about 30 % of global terrestrial soil organic carbon (SOC). Under proper grazing management conditions, rangelands have the potential to sequester significant amounts of additional carbon, and hence offset anthropogenic carbon emissions and contribute to mitigating climate change. Due to the heterogeneity of rangelands worldwide and notable scarcity of data in particular in Africa, attempts to estimate the impact of grazing effects on carbon in these ecosystems are a challenge. Hence, recommendations for management across different regions cannot be made. In this work, we used the DAYCENT ecosystem model to study SOC stock dynamics for a rangeland in Eastern Kenya. Operated as a livestock ranch with wildlife grazing as background noise, vegetation in this area is a mix of C4 grasses and a few stands of Acacia trees and shrubs. The effects of two soil types - sandy and clayey - and varying levels of grazing management - high, moderate and light long-term grazing intensities based on percentage removal of standing biomass - on SOC dynamics and sequestration potentials over a period of 15 to 20 years were estimated. The presentation will summarise major results of this study and will provide recommendations on grazing regime strategies for rangeland policy planning in the East-African region.

**Keywords:** Carbon sequestration, DAYCENT, grazing management, rangelands, soil organic carbon

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## Pastoral Dairy Development for Food Security and Food Safety in Eastern Africa: Challenges and Potentials

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Pastoralism is a source of income as well as food and nutrition security for about 20 million people in the drylands in Eastern Africa. Most interventions for pastoral development have focused on meat production, but pastoralism is a multifunctional system in which milk also plays an important role. Greater emphasis on dairy development could improve the nutrition of pastoralist families and other local consumers of milk products in the drylands and could strengthen the role of pastoralist women as the traditional managers of milk and as innovators in dairy micro-enterprises.

In order to inform particularly European but also African policymakers about the challenges and potentials of pastoral dairy development, CELEP (Coalition of European Lobbies for Eastern African Pastoralism) reviewed literature and project experiences related to dairy development in Eastern Africa. It looked into the differences between what are commonly described as formal and informal milk markets, including evidence concerning food safety in these markets. It gave particular attention to the specificities of pastoral dairying, which call for a different approach to dairy development in the drylands than in agrarian areas such as the highlands. However, similarities between the two areas were also found, in that many small-scale milk producers struggle to fulfil formal-sector requirements. The review investigated the contribution of pastoral dairying to nutrition in the drylands and the potential contribution of pro-poor dairy development to women's empowerment and wider food security.

After considering the potentials and constraints in pastoral dairy development, CELEP formulated recommendations regarding European policies and development interventions in this sector in Eastern Africa. The partner organisations of CELEP in Eastern Africa are developing corresponding recommendations for policymakers in their respective countries and the region.

**Keywords:** Dairy development, drylands, Eastern Africa, food safety, food security, markets, pastoralism, policy, small-scale milk production, women

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## **Spatio-Temporal Analysis of Land Use Land Cover Change in East Pokot, Kenya**

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Multispectral Landsat surface reflectance products at 30 m spatial resolution from Landsat 4/5 Thematic Mapper, Landsat 7 Enhanced Thematic Mapper Plus and Landsat 8 Optical Land Imager were classified to five classes i.e. water, maize fields, bare soil, dense shrubs and trees and shrub savannah using random forest algorithm for the years 1985, 1990, 1995, 2000, 2005, 2010, 2015 with overall accuracy of 91.38 %, 92.48 %, 90.68 %, 88.59 %, 89.68 %, 87.11 % and 87.55 %, respectively. Analysis of the land use land cover change (LULC) revealed the spatial trend of maize cultivation. There is around sevenfold increase in maize fields in last 30 years, from 1104.21 ha in 1985 to 8176.14 ha in 2015, signifying that this region is gaining agricultural dependency esp. in maize for food security. Apart from East Pokot counties near Baringo Lake, the new counties in East Pokot near Turkana are identified as new area for maize cultivation. The expansion of maize cultivation is attributed to the intervention of the government of Kenya and development partners to promote food security along with the resolution of the armed conflict in the region. The region is also experiencing bush encroachment over the last 30 years which coined the decrease in availability of shrub savannah and grazing grassland for the pastoralism. These results will definitely assist planners and development workers to a long-term portrait of the rangeland pastoral LULC allowing mobile grazing pastoralism with balanced agriculture extension ultimately conserving the historical culture of East Pokot. The study also showed a significant positive relationship between spectral reflectance and tasseled cap components greenness, wetness and dryness, indicating the remote sensing offers trustworthy resource assessment and monitoring options for informing, planning and interventions in semi-arid regions.

**Keywords:** Land use land cover change, maize, rangeland pastoral grazing resource trend, tasseled cap

## Analysing Pastoral Resources Use and Regional Livestock Mobility in West Africa for Improved Livelihoods: An Interdisciplinary Study of African and German Universities

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Pastoralism is both a lifestyle and a livestock production system based on livestock mobility and on the exploitation of natural pastures. In West Africa, cross-border livestock mobility is increasingly recognised as an effective strategy for enhancing livestock productivity and ensuring the sustainability of pastoral livelihoods. Hence, the Economic Community of West African States (ECOWAS) has set up regional agreements and policies and put in place frameworks to regulate this practice. However, while most policy-makers have only limited understanding of pastoral systems, many pastoralists prefer to follow informal routes. This often results in conflicts with local pastoralists and crop farmers, which are escalating in the recent past but are still poorly studied. Moreover, herders' utilisation of different pastoral resources including grassland, browse, water and animal genetic resources along the transhumance routes require more scientific attention in view of elaborating economically and ecologically sound herd and pasture management strategies. This contribution presents the structure and progress of a collaborative research project between scientists from the universities of Abomey-Calavi and Parakou and livestock farmers' associations in Benin, and the German universities of Kassel, Goettingen, and Giessen. The project, supported by Volkswagen Foundation Hannover through its funding initiative "Knowledge for Tomorrow - Cooperative Research Projects in sub-Saharan Africa", seeks to (i) analyse pastoralists' uses and management of natural resources (animals, rangelands and water) along the transhumance routes from the Sahel to the West African coast, (ii) quantify the effects of mobility on the productivity of both livestock and rangelands, and (iii) derive recommendations for increased herd productivity, conservation of biodiversity and animal genetic resources towards improved livelihoods of pastoralists in the region. The interdisciplinary project hereby integrates methods from the social and natural sciences and generates comprehensive knowledge to inform supportive policies that prevent over-exploitation and degradation of the pastoral resources.

**Keywords:** Animal genetic resources, livelihoods, pastoralism, rangelands

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## High Impact Grazing Enhances Grass Forage Quality in Northern Argentina

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Natural grasslands are the major feed source for livestock in the Province of Corrientes, northern Argentina. Traditional extensive-management on large paddocks with low stocking rates favours the accumulation of low quality, grazing deterrent standing dead biomass. Soils are frequently waterlogged and biomass elimination with machines is impracticable. Since biomass burning has been out-lawed, range managers are looking for management alternatives to eliminate the dead biomass and to stimulate the regrowth of nutritious grass.

High impact grazing (HIG) was proposed as an alternative to address this problem in Argentina. HIG is using the effect of large herds which eliminate standing biomass by trampling and forage intake during a short term high intensity grazing. The aim of this study was to evaluate the effects of HIG applied in different seasons on fodder quality. Quality parameters crude protein (CP, in g 100 g<sup>-1</sup> DM), metabolisable energy (ME, in MJ kg<sup>-1</sup> DM), and digestible organic matter (DOM, in g 100 g<sup>-1</sup> DM) were analysed up to one year after HIG and compared to control sub-plots under standard grazing regime. Compared to the control, HIG in winter produced more CP, 6.0 vs 4.9 ( $p = 0.004$ ); more ME, 5.2 vs 4.7 ( $p < 0.0001$ ) and more DOM, 40 vs 37 ( $p = 0.0002$ ). HIG in spring did not affect CP 5.6 vs 4.8 ( $p = 0.0624$ ); but increased ME, 5 vs 4.8 ( $p = 0.0284$ ) and DOM, 39 vs 37 ( $p = 0.017$ ). HIG in autumn increased CP, 6 vs 4.9 ( $p = 0.0026$ ); ME, 5.1 vs 4.7 ( $p = 0.0003$ ) and DOM 39.7 vs 37.2 ( $p = 0.0021$ ). HIG in summer did not affect the quality parameters; nevertheless, from a management point of view it still could be favourable as it reduced the dead biomass. Timely-well managed HIG not only reduced this pool, but it also delivered increased fodder quality. We have shown that forage quality was enhanced during autumn, winter and spring after HIG. The positive effects lasted for up to 4 months, which would be enough to improve fodder quality for livestock throughout the unfavourable winter. Further studies should assess the effects of repetitive HIG that could maintain these positive effects.

**Keywords:** Corrientes, environment, fire, fodder, management

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# Model-based assessment of climate change impacts

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## Screening of Livestock Feed Resources Owning Low Enteric Methane Emissions for Sustainable Food Security in Sub-Sahara Africa

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Livestock sector accounts for 40 % of agricultural domestic product. Food from animal sources contributes 18 % of global calories (kcal) and 25 % of global protein consumptions. However, livestock sector contributes to green house gas (GHG) emissions causing global climate change. The most important GHG emitted from the livestock agriculture is methane (CH<sub>4</sub>), which originates from enteric fermentation and manure. Ruminant animals reared in Sub-Sahara Africa are usually fed on tropical forages and produce high enteric CH<sub>4</sub> due to poor digestibility and nutrient content. Thus, searching for alternative livestock feed resources with possible low CH<sub>4</sub> emission while owing better nutrient quality would be justifiable. With this research gap in mind, 48 plant materials (foliages and pods of multipurpose trees, legume and grass forages, leaves of root crops, fruit waste and agro-industrial byproducts) were tested *in vitro* for their potentials to mitigate CH<sub>4</sub> emission. Results indicated that among the investigated multipurpose trees, leaves of *Prosopis juliflora*, *Cajanus cajan*, *Leucaena leucocephala*, *Acacia nilotica* and *Moringa oleifera* as well as pods of *Millitia ferruginea* and *P. juliflora* produced the lowest CH<sub>4</sub>. *Panicum colouratum* and *Desmodium intortum* were found to be suitable tropical forages in reducing CH<sub>4</sub>. Sweetpotato and cassava leaves among root crops as well as Mango seed kernels and *Moringa* seeds from fruit byproducts were identified as potential candidates in mitigating CH<sub>4</sub> emission. In conclusion, leaves of those multipurpose trees and root crops as well as fruit byproducts that were identified as potential candidates for reduced CH<sub>4</sub> can be used as protein and energy supplements to poor quality forages and crop residues for practical mitigation of CH<sub>4</sub> emissions from ruminants. Moreover, those forages that showed the lowest CH<sub>4</sub> can be fed alone or in combinations to supplement tropical feed resources. We recommend animal-based experiments to validate the actual feeding values of the identified feed materials and assess their production potential.

**Keywords:** Forage crops, fruit byproducts, methane emission, multipurpose tree foliage, nutrient compositions, root crop leaves

## Effect of Intensification of Crop Management on Cereal Crop Yields under 1.5°C and 2.0°C Global Warming in the West African Sudan Savannah

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Rainfed cereals are the main staple food crops in the West African Sudan Savannah. While current yield levels are low due in large part to the limited use of fertilisers, sustainable intensification of cropping systems is widely promoted in the region to improve food security and drive regional economic development. However, an important consideration is increased interannual yield variability and possible interactions with climate change, as this represents an important source of risk for farmers. This study assessed the effect of intensification on maize, pearl millet and sorghum yields under 1.5°C and 2.0°C global warming in the West African Sudan Savannah. Simulations were conducted with two crop models (DSSAT and Lintul5 embedded into the SIMPLACE modelling framework) at a spatial resolution of 0.25° under both current fertiliser use and optimum fertiliser application (intensification case). The models were calibrated with local varieties from field experiments in the region with management reflecting a range of typical sowing windows. Results indicated that yields simulated under intensification were two to three times higher than yields simulated under current fertiliser use, irrespective of the warming scenario. However, yield losses under

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climate change were slightly higher with intensification: 2 % units higher for maize and sorghum with 2.0°C compared to 1.5°C warming, with no change in millet yields for either scenario. As expected, interannual variability increased with intensification compared to current fertiliser use, though there was no interaction with climate change scenario. In summary, it is suggested that intensification would much more than offset the negative impacts of climate change, though economics analysis is required to understand the implications for risk and constraints on market development needed to support intensification.

**Keywords:** 1.5°C, climate change, intensification, West Africa

## Modelling Long-Term Impacts of Climate Change on Rubber Plantations and Options for Adaptive Forest Management

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Rubber plantations have expanded rapidly in Montane Mainland South East Asia in past decade. The impact of long-term environmental changes on carbon stock dynamics of rubber plantations is constrained by site-specific growth conditions and still not fully understood. In order to improve regional forest management, we jointly used field survey and modelling tools to predict rubber biomass development at tree-, plot-, watershed- and landscape- scale in Nabang National Nature Reserve, Xishuangbanna. Rubber trees/plots level parameters were used to calibrate the Land Use Change Impact Assessment (LUCIA) model. The potential response of tree growth (biomass annual increment) and latex production (latex annual increment) to various climate change scenarios was simulated from low CO<sub>2</sub> emission scenario (RCP2.6) to high CO<sub>2</sub> emission scenario (RCP8.5) for rubber plantation with a 40-year rotation length. These results were used in the large-scale forest scenario model EFISCEN (European Forest Information SCENario model) to upscale impacts of various climate- or management-driven scenarios into 2055. According to LUCIA simulation outputs, rubber plantations cultivated at high elevation (above 900 m asl) benefited more from future warming climate. The total biomass and cumulative latex increased 28 % and 48 % from baseline to RCP8.5. We also tested three scenarios with EFISCEN model applied at landscape level, namely: 1) climate promoted increase scenario - “growth increase scenario”, 2) other land use conversion into rubber plantations scenario - “species change scenario” and 3) combined impact scenario - “integrative scenario”. Simulations revealed obvious patterns of carbon stock increase in the growth increase scenario, i.e. the regional carbon stocks were increased by 30 % and species annual increments also increased by 50 %. Our simulations from EFISCEN model suggested that future climate change may greatly impact on rubber tree growth at large (landscape-) scale, while LUCIA simulation reported at tree- and plot- level the influence of climate change might be compensated or decreased by local management strategies. Combined process-based model and landscape scenario model applications for rubber-based system help in better understanding climate change impacts on ecosystems. Our results could be relevant also for other rubber-cultivated regions particularly thus in mountainous regions.

**Keywords:** Carbon sequestration, climate change, forest management, latex production, rubber-based system

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## Assessing Hydrological Ecosystem Services under Land Use and Climate Change Scenarios in a Mountainous Watershed

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The extension of large-scale cash crop cultivation in Montane Mainland South-East Asia brought new livelihood options for farmers, who previously kept the century-long tradition of swidden farming. This change in land use transformed entire landscapes and thereby potentially altered critical biophysical structures and processes. These serve as the basis for the provisioning of ecosystem services (ESS) such as fresh water supply or the prevention of erosion. How resilient these altered landscapes are with regard to preserving hydrological ESS in the face of a changing climate is yet to be understood. We chose the Nabanhe Reserve in Xishuangbanna prefecture (Yunnan province, PR China) as a study area, as it saw an extensive expansion of rubber plantations within the past decades. The aim of this study was to assess the effect of rubber-related land use changes under multiple scenarios of climate change. We developed three land use scenarios in cooperation with local stakeholders for the year 2040. These include a Business-As-Usual scenario, where past rubber expansion rates will be continued in a linear manner, the 5-Year-Plan scenario, which is based on regional policy plans, and the Balanced-Trade-Offs scenario, which incorporates conservation measures such as riverine buffer strips and water protection zones. The resulting land use maps were used in combination with spatially explicit precipitation data based on two Representative Concentration Pathways (RCP 4.5 & RCP 8.5) of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC5). Both represent main inputs to model sediment export and water yield on watershed scale with the InVEST (Integrated Valuation of Ecosystem Services and Trade-offs) software suite. The methodology applied here can easily be adapted to other regions, as InVEST and the IPCC5 data are either open-source or freely available. The results provide valuable information to develop mitigation strategies in order to buffer adverse effects on hydrological ESS resulting from long-term changes in precipitation patterns.

**Keywords:** Climate change, ecosystem services, InVEST, land use change, rubber, scenario modelling

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## Developing a Multi-Scale Model for Sustainable Water Management in Vietnam's Mekong Delta

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The Mekong River Delta in Vietnam (VMD) is the world's third largest river delta, and is an important agricultural area providing for a large proportion of national rice production. To adapt to changing environmental conditions during the dry and wet season, low-lying coastal farms practice a rotational rice-shrimp system. However, decreasing freshwater availability, especially from rainfall, impedes the transition from shrimp to rice, and has forced many farmers to shift towards a more profitable shrimp monoculture system. Consequently, coastal areas lose their protective function against seawater intrusion deeper inland, and salt concentrations in ground and surface water increased along with the associated salt accumulation in the soil. Climate change impacts, such as rising sea level, shifts in precipitation patterns, and freshwater scarcity will accelerate salt water intrusion and are a major threat for ecosystems, environments, and food security particularly in Asian Mega Deltas. This study presents a modeling concept to develop a sustainable water management and land-use approach, including spatial and temporal adaptation and mitigation strategies, for rice farmers in the VMD. Seasonal dynamics of flooding and salinity, and other related water problems, such as freshwater scarcity will be considered. The study uses a multi-scale modeling approach by linking two models: (1) Water evaluation and planning system (WEAP) for crop-water requirements and soil-water dynamics in the catchment; (2) MODFLOW and MODPATH for simulating groundwater flows, soil-groundwater interactions and salinity concentrations in the groundwater. The results of the model will be validated with data collected in three different case study sites, representative of different conditions in the delta. The results will show varying salinity levels and freshwater availability in different temporal and spatial scales to identify hotspots of production constraints. Different management options, such as dynamic irrigation techniques to improve freshwater availability and reduce salt concentrations in soils and groundwater throughout the delta, will be tested in the model.

**Keywords:** Integrated management, land-use change, MODFLOW, MODPATH, rice, sea-level rise, WEAP

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## The Carbon Footprint of Cotton Production in Xinjiang, China

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Agriculture contributes to and suffers from global climate change at the same time. In China, which is the world's largest GHG emitter, emissions from agricultural sources increased by around 50 % over the last 20 years. Hence, it is important to evaluate the sources of GHG emissions from crop production and identify opportunities for emission reduction. Cotton (*Gossypium hirsutum* L.) as the most important cash crop in China supplies feedstock for the national textile industry and contributes to rural incomes and development. However, cotton is a very resource intensive crop with significant environmental impact. We selected Xinjiang province for our study, as it is the most important cotton production region in China, contributing around 10 % to global cotton production. The region features an ideal climate for cotton cultivation with high radiation and low precipitation. We interviewed more than 200 cotton producers on their detailed crop management including all material inputs like seed and fertiliser, their use of electricity and diesel as well as their cotton yield and by-product use. Applying a partial life cycle assessment approach, we calculated the GHG emissions per unit of land and the carbon footprint per produced unit of cotton for every specific farm. We found huge differences among farms indicating the potential for improving input use efficiency and yield levels to reduce emissions and improve carbon footprints. Energy for irrigation, fertiliser use and soil borne N<sub>2</sub>O emissions constituted the major emission sources. We furthermore found that farmers using modern irrigation technology excerpted higher emission per unit of land. However, their higher yield levels overcompensated and resulted in lower carbon footprints per produced unit of cotton. The study highlights the potential for reducing the climate change impact of cotton production through improved crop management.

**Keywords:** Carbon footprint, China, cotton, farm survey

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## Pathways through which Climatic Shocks Affect Child Undernutrition: A Structural Equation Modelling

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The past three decades have seen a striking change in climatic conditions. Globally, an increase in average temperature, greenhouse gas concentration, and anthropogenic CO<sub>2</sub> emissions have been recorded. These changes carry worrisome consequences for the planet earth including ocean acidity, increase in permafrost temperature, change in snow cover and decrease in Arctic sea-ice which in turn leads to the frequent occurrence of cyclones, droughts, floods, heat waves and wildfires and leaves billions at risk of malnutrition and illnesses. Using three rounds of the young lives cohort study dataset this study aims to identify the pathways through which climatic shocks affect child undernutrition and health. To this end, the study employed a structural equation modelling to empirically test the pathways through which climatic shocks affect child undernutrition based on the UNICEF conceptual framework. 1980 younger and 982 older cohort children were included in the main analysis. Results show a significant negative association between climatic shock and linear growth that is mediated by increased food insecurity and poor environmental and service conditions which in turn lead to lower child dietary diversity and poor child health status. Moreover, in this study the magnitude of the effect of climatic shocks on environmental and service conditions was higher than their effect on food insecurity for both height-for-age (YC- $\beta_{FI}=.15$ ,  $\beta_{ES}=.54$  & OC - $\beta_{FI}=.23$   $\beta_{ES}=.73$ ) and BMI-for-age (YC- $\beta_{FI}=.15$   $\beta_{ES}=.57$  & OC - $\beta_{FI}=.21$ ,  $\beta_{ES}=.62$ ) models. The implication of the results is that programs aiming to curb the negative impacts of climatic shocks should invest more on improving environmental and service conditions in addition to combating food insecurity. This could be achieved by incorporating other determinants of nutrition into programs through increased access to health services, sanitation and nutrition education. Moreover, in this study, households report of climatic shocks was positively correlated. Therefore, diversifying the means of livelihoods, social protection schemes, and access to credit should be considered as a policy alternative for recurrently affected populations.

**Keywords:** Climatic shock, Ethiopia, climate change, structural equation modelling, undernutrition, young lives data

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## Estimation of Enteric Methane Emission Factors and Intensities in Smallholder Cattle Systems in Western Kenya

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Data on methane (CH<sub>4</sub>) emissions from cattle in sub-Saharan African (SSA) are scarce, outdated, and commonly derived from the Tier 1 methodology, and thus not specific to prevailing systems. Tier 2 methodology, based on area-specific feed and cattle characterisation, would improve accuracy and lower uncertainties on CH<sub>4</sub> emissions estimates for cattle systems in SSA. Hence, the objectives were i) to estimate enteric CH<sub>4</sub> emission factors (EF) and emission intensities (EI) for meat and milk production using IPCC Tier 2 methodology, and ii) to evaluate uncertainties related to Tier 2 EF estimates in cattle systems of western Kenya. Cattle herd feeding and productivity were characterised in twenty villages of three geographic zones in western Kenya over four seasons of one year (n=388 cows). Cattle were disaggregated by age and production stages. Seasonal ingredient composition of cattle diets was established from the available feed biomass. Feed samples were collected and their apparent total tract organic matter digestibility estimated from analysed proximate nutrient concentrations and *in vitro* gas production. Animal performance was evaluated using liveweight (LW) measurements, body scoring, milk yield, and number of hours worked. The animals' net energy requirements, gross energy intakes, and EF were calculated following IPCC Tier 2. Uncertainty analysis was performed using coefficients of variation method and individual uncertainties combined to give overall uncertainty using IPCC propagation of errors method. By dividing EF by annual milk or meat production of individual animals, EI were calculated (in carbon dioxide equivalents; CO<sub>2</sub>eq.). Tier 2 EF were 20–29 kg CH<sub>4</sub> for young, 34–63 kg CH<sub>4</sub> for adult females, and 40–50 kg CH<sub>4</sub> head<sup>-1</sup> year<sup>-1</sup> for adult males. The EI ranged from 56 to 100 kg CO<sub>2</sub>eq. kg<sup>-1</sup> meat and from 4 to 32 kg CO<sub>2</sub>eq. kg<sup>-1</sup> milk. Milk yield, LW, and diet digestibility contributed most to overall uncertainty in EF estimates (i.e., 52 %, 20 %, and 13 % of cumulative uncertainty, respectively). Smallholder cattle likely emit more CH<sub>4</sub> than Tier 1 estimates of their emissions. The EI reveal great potential for mitigation of emissions by increasing cattle productivity. Accurate milk records, LW, and diet digestibility would reduce uncertainty in EF estimates.

**Keywords:** Cattle systems, emission factors, emission intensity, uncertainty

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## Modelling the Vulnerability of Fisheries and Aquaculture to Climate Change Impact

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Climate change as result of global warming remains one of the major threats to aquaculture, fisheries and dependent communities worldwide. Vulnerability of aquaculture and fisheries to climate change is a function of exposure, sensitivity, and adaptive capacity of the community in question. Vulnerability of fish farmers is largely determined by the differences in socio-economic conditions among communities. This study aims to determine factors influencing the vulnerability of fishers and fish farmers to climate change impact in Africa. The objectives are twofold: first, to develop indicators influencing vulnerability and to determine how they influence vulnerability, secondly, to compare the vulnerability of fishers and fish farmers in different regions of Africa. Using the most recent data twenty-seven countries in Africa were evaluated using seventeen indicators, which are allocated into the three components of vulnerability; the exposure, sensitivity and adaptive capacity. Results shows that vulnerability of fisheries and aquaculture to climate change impact is driven by poverty, low human development index and high occurrence of natural disasters. The most vulnerable regions in Africa are the west, central, East and North Africa regions. The southern regions of Africa tend to be less vulnerable to climate change impact on fisheries and aquaculture. Our result shows that establishment of marine protected area and investment in poverty alleviation will decrease vulnerability to climate change impact on fisheries and aquaculture. The findings from this research will enable the formulation of policy recommendations to help strengthen the livelihoods of small-scale fisheries and aquaculture in Africa.

**Keywords:** Aquaculture, climate change, fisheries

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## Improved Greenhouse Gas Emissions and Nutrient Losses Estimates from Manure of Kenyan Smallholder Dairy Farmers

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African agriculture produces 15 % of the global agricultural greenhouse gas (GHG) emissions, with 25 % of these GHG emissions from the African continent attributed to manure and manure management. To date few studies are available that focus on manure management within smallholder dairy farming systems and the subsequent GHG emission estimates. There is need to improve GHG inventories in sub-Saharan African (SSA) countries. The study region was located in western Kenya and prior to data collection stratified into three agro-ecological zones (AEZs). From the zones, we identified animal confinement systems, main manure management systems and duration of storage of manure. CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management were then estimated for the region using both Tier 1 and Tier 2 IPCC guidelines. GHG flux measurements from manure piles that were collected from the animal confinements previously characterised, were carried out using non-flow through, non-steady state GHG chambers. Measurements lasted for a period of 90 days. Leachate was collected daily via an inbuilt drainage tube with solid manure sampled from the heaps periodically. Annual CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management systems in Nandi County using Tier 1 were 0.22 Gg CH<sub>4</sub> yr<sup>-1</sup>, 0.16 Gg N<sub>2</sub>O yr<sup>-1</sup> and categorization of manure management systems for SSA leads to lower Bo and hence lower MCF and lower Tier 2 CH<sub>4</sub> emissions (0.002 Gg CH<sub>4</sub> yr<sup>-1</sup> and 0.031 Gg N<sub>2</sub>O yr<sup>-1</sup>) than Tier 1. Methane emission factors from manure management were higher using the Tier 2 than the currently used Tier 1. The confinement systems “Fence Only”, “Fence and Roof” and “Fence, Roof and Floor had significant differences in cumulative CH<sub>4</sub> but not for cumulative N<sub>2</sub>O emissions. Mean nitrogen (N) lost from the manure through leaching ranged from 2.0 g N to 2.1 g N. This study provides a mechanism to improve Tier 2 GHG emission calculations for manure management in smallholder farming systems in SSA that could help identify practices to reduce GHG emissions originating from agriculture. The over 40 % loss of nutrient N from manure provides for further justification on the need to improve manure management for smallholder farmers. Furthermore, improved manure management allows smallholder farmers to benefit from the manure are fertiliser by returning essential nutrients to the soil.

**Keywords:** Dairy, East Africa, greenhouse gases, manure, smallholder

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## Seasonal Forecasts for the Horn of Africa: Evaluation of the Skill of Convection-Permitting Simulations

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Global seasonal forecasts provide helpful information. Today's resolution is 30 km or lower, which is still too coarse in orographically structured terrain, specifically for precipitation forecasts. Dynamical downscaling of such forecasts to convection-permitting (CP) scale (grid size 1–4 km) has not yet been tested in African regions due to the lack of computational resources. In addition, the computational constraints limit the use of ensemble forecasts, which are generally more reliable: therefore the effectiveness of such strategy is not yet much analysed at the convection-permitting scale.

The Horn of Africa is a highly challenging area for global models due to its complex topography. The Ethiopian highlands strongly influence the climate and a relatively small area experiences very different precipitation regimes, sharp changes in temperature and seasonal fluctuations. Other projects have shown that downscaling seasonal forecasts at a lower resolution (25 km) has little to no impact on the forecast skill.

This work aims to study the ability of a convection-permitting model to provide seasonal forecasts for the Horn of Africa with added value with respect to their global counterparts. Specifically, air temperature and precipitation bias will be considered as key elements for the evaluation of the model performance. The weather research & forecasting (WRF) model is used, coupled with the Noah-MP land-surface model, to downscale the ensemble seasonal forecasts produced by the European Centre for Medium-Range Weather Forecasts (ECMWF).

Preliminary work shows that downscaling global model output using such a high-resolution model improves the precipitation patterns over the considered domain, both the location and the total amount.

**Keywords:** Convection-permitting scale, dynamical downscaling, Horn of Africa, seasonal forecasts, WRF

## Multi-Temporal Biomass Estimation of Vegetable Crops Using Unmanned Aerial Vehicles

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3D point cloud analysis of imagery captured by unmanned aerial vehicles (UAV) are depicted to be a valuable tool for estimation of crop phenotypic traits (e.g. crop height) in several crops. Spatial information about these traits can be used to derive information about other important crop characteristics (e.g. biomass), which could not be derived directly from the point clouds. Previous approaches have often only considered single date measurements using a single point cloud derived metric for the respective trait. The aim of this study was to assess the applicability of UAV imagery by capturing the crop height information of three different vegetable crops (eggplant, tomato, and cabbage) during a complete crop growth period to infer the biomass. Additionally, the effect of crop development stage on the relationship between estimated crop height and field measured crop height was examined. The study was conducted in an experimental layout at the University of Agricultural Sciences in Bengaluru, India. The three crops height and the biomass were measured at five sampling dates during the crop growth period from February to May 2017. Each plot was measured using an UAV, equipped with a photo camera. Using a structure from motion approach a 3D point cloud was created for each crop and sampling date. In total 14 crop height metrics were extracted from the point clouds. Machine learning methods were used to create prediction models for vegetable crop height. The study demonstrates that the monitoring of crop height during an entire growth period using several crop height metrics of biomass with more detailed estimates of crop height and biomass is better than single date and single metric approaches. Altogether the results of the study encourage that UAV based remote sensing tools can be used to effectively measure vegetable crop biomass in larger areas. In future studies, the interrelated effect of other phenotypic traits (e.g. leaf area index) on the relationships found should be tested.

**Keywords:** 3D point cloud and phenotypic traits, unmanned aerial vehicles

## Optical and SAR Data for Mapping of Complex Irrigated Agriculture Regions: A Case Study in Punjab, Pakistan

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Accurate information on land use is very important to ensure all humans have access to food for healthy living. Remote sensing has gone through many advancements in the recent years with the launch of new optical and synthetic aperture radar (SAR) satellites. This study compares the effectiveness of optical and SAR imagery alone and in combination for complex cropping region of Punjab, Pakistan. Lower Chenab Canal command area, located in Punjab province, one of the major and more complex-cropping regions was selected. Smaller field size, diverse cropping patterns, and cloudy climate especially during monsoon season make it difficult for mapping using coarse spatial resolution, and optical data. Optical and SAR data from Sentinel II & I were used after processing for normalized difference vegetation index (NDVI), and back scattering (Sigma0), respectively. Supervised classification using random forest algorithm was performed on three data-sets i.e NDVI, Sigma0 and integrated use of NDVI and Sigma0 for summer season (i.e. May to October 2017). For training of model, 75 % ground truth points were used and the 25 % rest were used for accuracy assessment. All the major crops in summer season including rice, cotton, sugarcane, maize and fodder were mapped and accuracy of classified maps were checked using error matrix. The results showed that separate use of NDVI and Sigma0 for both polarisation produced overall accuracy of 71 % and 72 %, respectively. The kappa coefficient with these two data-sets were 0.64 and 0.66, respectively. The integration of NDVI and Sigma0 shows increase in overall accuracy and kappa coefficient. The overall accuracy and kappa coefficient for combined data-set were 77 % and 0.71 % respectively. The results encourage the combined use of optical and SAR data to improve the mapping accuracy in regions with heterogeneity and cloudy climate.

**Keywords:** Fusion, LULC, random forest, remote sensing, SAR

# **Agroforestry and soil quality**

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# Agroforestry and tree crops

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## Arabica Coffee in Mixed Cropping Systems – A Contribution to Sustainable Highland Agriculture and Food Safety

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Highland areas are fragile ecosystems and in northern Thailand, livelihoods of highland farmers depend on the sustainable use of natural resources. Arabica coffee (*Coffea arabica*) was introduced by the Royal Project Foundation (RPF) to improve farmers' incomes and at the same time, introduce mixed cropping systems that are better adapted for the highland agro-ecosystems.

Focusing on the observation of plant growth, leaf rust incidence, yield and good cupping, 14 varieties from different RPF planting sites were collected and planted at the RPF Inthanon Research Station, Chiang Mai, Northern Thailand. Five sampling varieties namely A3, A4, A5, A6 and A8 showed tolerance against leaf rust and were rated highest in terms of cupping, scoring 80–82 points according to the SCAA standard. Propagating these varieties will create a sturdy base for low pesticide coffee production.

To improve quality and yield, at the RPF Development Centers Pamiang and Teen Tok, Chiang Mai, coffee plants were grown under shade trees and hard pruning was applied. This system was compared to farmers' practice. Results show that pruned trees yielded an average of 3.2–4.5 kg tree<sup>-1</sup> of fresh beans, which is significantly higher than yields of farmer plots.

Sustainability aspects of coffee production were studied at Wawee RPF Extension Area, Chiang Rai. The objective was to demonstrate RPF knowledge on improving quality and yield of coffee by integrated farm management for soil and water conservation. Shade was created by intercropping with banana, *Fraxinus* (*Fraxinus griffithii*), Indian Gooseberry (*Phyllanthus emblica* L.) and Macadamia nut. Two years experiment show that coffee trees trend to have significantly higher fruiting as compared to conventional farmers' practice. Shade trees offer additional products and contribute to restore and conserve soil fertility and water holding capacity. In addition, insect pests and diseases decreased by up to 15 %, whereby farmers can reduce the use of agro-chemicals considerably. Thus, farmers collaborating with the RPF are able to achieve high yields at good quality, without chemical residues.

**Keywords:** Coffee, Royal Project Foundation, rural livelihoods, Thailand

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## Profitability of Agroforestry-Based Biofuel Value Chains in India

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Energy security is an essential condition for food security and rural poverty reduction in developing countries. To achieve increased independence from expensive fossil fuels for transport and electrification in poor landlocked areas, a search for affordable, more sustainable and alternative energy sources was recently initiated. Liquid biofuel production in small-scale agroforestry systems for local use is considered a promising option. In this novel approach multipurpose oilseed trees are integrated within existing farming systems. Although oilseed yields might be limited in these low input – high diversity – high resilience systems, the trees bring along multiple other products, uses and co-benefits, which add to the viability of the approach.

Such a biofuel model is being implemented in Hassan district, South India, but empirical studies have shown that current farmer participation is low, and that willingness to participate heavily depends on the economic profitability of oilseed collection. To assess the model's economic potential, this study uses primary survey and yield data to quantify its long-term profitability for various value chain actors and designs. It aims to determine whether, under which configurations, for whom, and to which extent biofuel value chains are profitable, and how this depends on a range of (uncertain) key factors, such as prices and policies, technology and yields, and opportunity costs of land, labour and capital.

The results show that labour is a crucial factor for profitability. In most scenarios, it is not viable for farmers to hire labour for cultivation and processing. If family labour is used to this end, the economic potential is higher, although returns to labour would only improve from current values for part of the households, indicating programme targeting should be accordingly differentiated. Also land opportunity costs are vital to consider, as profits only start to surpass these after 10 years. From the viewpoint of processors, conversion of seed oil to biodiesel is currently irrational, as the former is a more valuable product under the prevailing economic conditions. Biodiesel production is only viable in a minority of scenarios, questioning the feasibility of the programme as a biofuel program.

**Keywords:** Agroforestry, biofuels, profitability modelling, rural development, value chain design

## Gendered Knowledge and Preferences of Food Trees for Addressing Food Security and Nutrition Needs of Communities in Uganda

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Food trees play a central role in rural livelihoods and can contribute substantially to food and nutrition security. Farmers have a wealth of local knowledge and prioritise food tree species for cultivation and use for various household needs. This local knowledge and preferences are often not adequately considered during research development endeavours. This study sought to understand farmer preferences for food tree species to improve food and nutrition security in Uganda with respect to local priorities. The purpose was to identify sets of species which are ecologically adapted and seasonally available and fill specific food insecure periods and 'nutrient gaps' in diets, while responding to various gender and age-related needs, interest and constraints. Data collection was conducted using focused group discussions in two districts in Uganda, Nakaseke and Nakasongola. Participatory research using seasonality calendars and score - ranking was applied with eight groups of 80 participants, 40 women and 40 men segregated by gender and age to understand knowledge and preferences for food trees. A total of 36 important food trees species were listed, of which 17 were indigenous and could be used to fill food and nutrition gaps during food insecure months. The total number of food trees listed differed between genders, older women (aged 37 to 59 years) identified 22 species, younger women (aged 19–30 years) identified 19 species and older and young men identified 15 priority species. Score-ranking revealed that both men and women preferred exotic food tree species such as *Mangifera indica* (mango), *Passiflora edulis* (passion fruit) and *Persea americana* (avocado). Preliminary findings show that the most important considerations for scoring were: use of species for consumption, taste, medicinal value and opportunities for income generation. The latter was notably cited by both old and young men but also by young women. Findings shows availability food tree species that fill food and nutrition gaps and the value of gender-sensitive participatory research for understanding local knowledge and preferences, and their relation with farmer's needs and constraints, to inform project implementation decisions

**Keywords:** Food trees, gender, local knowledge, participatory community research, priority setting, Uganda, youth

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## Macaw Palm (*Acrocomia aculeata*) – A Minor Crop of the Neotropics with High Bioeconomic Potential

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Rich in biodiversity, the neotropics host huge resources for food security and income generation. Macaw palm (*Acrocomia aculeata*) found from Mexico down to Argentina is one example with excellent bioeconomic potential. It has manifold uses, e.g. food specialties, fodder, fibre or medicine. Its main product, however, oils from fruit pulp and kernel may boost its importance, as it is an economic, sustainable and environmental friendly alternative to *Elaeis guineensis*, adapted to less fertile soils and less favourable environmental conditions. We studied growth and light interception in sole and mixed cropped pioneer plantations in Paraguay. Aboveground biomass (5.6, 12.3, 19.1 Mg ha<sup>-1</sup>, resp.) and leaf area index (0.32, 1.09, 1.49, resp.) increased with age (29-, 69-, and 88-month-old), whereas light transmission (78, 41, 32 %, resp.) decreased. In the oldest stand, photosynthetic active radiation penetrating through the canopy still reached up to 1000  $\mu\text{mol m}^{-2} \text{s}^{-1}$  during 8.30 a.m. and 3.30 p.m., allowing to grow food crops below the canopy of macaw palms, an interesting option for peasant farms. Root observations also showed that their distribution is favourable for intercropping with other crops. First whole-farm-mathematical-modelling results from East-Paraguay indicate cropping potentials, especially for peasant farmers agroforestry systems. Currently, macaw palms start flowering after 48 months, producing fruits up to 70 years and more. Fresh fruit yields are around 22 Mg ha<sup>-1</sup>, providing up to 3.3 Mg ha<sup>-1</sup> of kernel and pulp oils, being high for a hardly domesticated species. Its composition of fatty acids with a share of essential fatty acids up to 60 % being higher than that of *E. guineensis*. Macaw people has the additional advantage that its fatty acid composition alters with the ecological conditions under which it grows. Hence, it is highly flexible in its application. In addition, they are rich in tocopherols and carotenoids. Finally, there is need to identify the best accessions for each ecological condition under which it grows to develop varieties tailored for specific applications in bioeconomy

**Keywords:** Agroforestry systems, farm modelling, multi-purpose applications

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## Leafy Vegetables under Shade? Performance of Cowpea (*Vigna unguiculata* (L.) Walp.) in a Multistorey Coffee Forest in Southwest Ethiopia

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In Yayu Coffee Forest Biosphere Reserve in Oromiya region, Southwest Ethiopia, people eat starch based diets with little fruit and vegetables. Micronutrient deficiency is likely to be widespread such as iron deficiency with anaemia rates among women and children being as high as 64 % in Oromiya region. The main income source from agriculture is coffee which is cultivated in a multistorey cropping system using shade trees. Outside the biosphere reserve and in its transition zone where people reside, it is allowed to cut trees and to cultivate the land. Here, crop production is threatening the existence of the remaining forest patches. Integrated vegetable production underneath the coffee and shade trees could help add another economic layer to the system and improve the availability of leafy vegetables for better nutrition. Previous research in Yayu had shown that cowpea (*Vigna unguiculata* (L.) Walp.) grew more vigorously than other vegetables under shade but how to optimise the leaf yield was still unknown. Therefore, the objective of the study was to test cowpea in shaded conditions for leaf production under two different harvesting regimes. Trials were set up in Yayu between April and December 2017 in a randomised complete block design comparing repeated harvest of single full leaves with a total harvest at the end of the trial. Plant development and growth was monitored on a weekly basis. Repeatedly harvested cowpea produced significantly more leaves than cowpea that was harvested once-over. Although cowpea under shade developed slower than cowpea in open field conditions, coffee forest farmers in Yayu would be able to continuously harvest leafy vegetable cowpea during the majority of the rainy season from land that previously only produced coffee yield. The consumption of vegetable cowpea could improve nutritional health as the leaves contain about 500µg/100g of Vitamin A which is often lacking in starch based diets. With about 3mg/100g of iron cowpea leaves contain about twice as much iron as Ethiopian kale, the single most popular leafy vegetable in Yayu. In 2018, the demand for and selling prices of cowpea leaves as vegetable will be assessed on the local markets in Yayu.

**Keywords:** Harvesting regime, nutrition, Yayu Coffee Forest Biosphere Reserve

## Agroforestry Options in Northwest Vietnam

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The mountainous northwest of Vietnam, bordering Lao PDR and China, is home for the majority of the country's ethnic minorities. Both poverty and food insecurity are common in the region. Slash-and-burn maize, rice and cassava monocultures have been the main source of local livelihoods for decades. However, increasing population and land scarcity have induced the expansion of agricultural areas and consequent decline of land productivity due to soil erosion and land degradation. For these reasons, slash-and-burn agriculture practices often fail to guarantee sufficient food and income. As a solution, local farmers have begun to practice agroforestry through the introduction of high value trees into traditional cropping systems. Since 2012, the World Agroforestry Centre (ICRAF) has trialled several agroforestry options in the region with various combinations of timber, fruit, nut forage trees and annual crops. However, because of inherent production risks and many remaining uncertainties, assessing the long-term performance of agroforestry has remained challenging.

Decision analysis is an approach that can address risk and uncertainty, which are expressed as probability distributions to provide a realistic picture of the range of possible system outcomes. The approach provides cost-effective basic assessment, which can be updated as more information becomes available. We simulated prospective system benefits of agroforestry options by developing comprehensive and holistic models that aimed to explicitly consider all relevant risks and uncertainties. Project managers and technical staff from ICRAF, local farmers and extension workers were asked to list all the costs, benefits and risks associated with the implementation of seven agroforestry options. Conceptual models were developed to map out causal relationships among identified input variables. The initial findings reveal model components such as drought and frost and potential extreme weather events as the primary risks to agroforestry in the region. The analysis approach is a promising tool for *ex-ante* assessments of other planned interventions.

**Keywords:** Decision analysis, food insecurity, holistic model, risk and uncertainty

## Impact Pathway Validation for an Agroforestry Intervention in Nepal

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Many development projects fail to produce intended outcomes. A major reason for this is that project interventions are often expected to trigger a series of events, which ultimately leads to impacts. Weak links in this causal chain can cause failure. To reduce this risk, it has become common practice among project managers to develop 'impact pathways', which make all causal linkages explicit, help anticipate problems and allow strengthening project design.

So far, impact pathways are rarely used after a project has started, with project evaluation focusing on comparing baseline with end line data. We propose using impact pathways to guide adaptive management of development projects. This can be achieved by treating the impact pathway as a collection of hypotheses about causal relationships between system components, which can be tested by targeted research. By evaluating causal linkages during project implementation, likely points of failure can be anticipated and possibly eliminated, allowing adaptive project management.

This rationale was applied to an ongoing agroforestry project in Nepal, which aims to enable farmers to introduce new tree species into their farms. The project's impact pathway was elucidated based on field observations, focus group discussions and participatory modelling sessions with project staff. Findings were synthesized into a conceptual impact pathway model that explicitly spelled out all cause-effect relationships that were needed for the project to be successful. A questionnaire was then designed with the specific aim of testing selected linkages in the model. Based on a survey of 40 farm household, confidence intervals for the strengths of the associations between elements of the impact model were estimated.

Many linkages, e.g. between training and tree introduction, or between increased crop production and more food for household consumption, were found to be strong. Other expectations of the impact pathway, however, could not be confirmed, e.g. a link between a high number of trees on a farm and high timber sales. Overall, results revealed an impact pathway that was most robust but contained some weak links that jeopardised the success of parts of the project. Impact pathway validation helped identify these weaknesses, providing valuable feedback to project managers.

**Keywords:** Agroforestry, evaluation, food security, impact pathway

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## On the Contribution of Planting and Use of Underutilised Local Food Tree Resources for Food Security and Biodiversity Conservation in Uganda

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Trees and forests are fundamentally important for the survival and wellbeing of humans and other ecological communities. They provide regulating, provisioning, cultural, aesthetic and supporting services; from air purification, climate regulation, carbon sinking, and water cycling, to fuel, timber, medicines, fodder, construction and fencing material. They facilitate soil formation, prevent its erosion, and provide habitat for and protection of biodiversity. Food-bearing trees play an even higher role; in addition to the values above, they provide food and for nutritional needs of humans, livestock and wildlife. Food-bearing trees are rich sources of vitamins, minerals, proteins, fats and other nutrients, thus capable of increasing food security and reduce malnutrition among beneficiary communities. A number of these (wild) food trees are underutilised; they only have local importance, lack markets, are hardly researched, and there are negligible efforts towards their protection, conservation or domestication.

While loss of tree resources is linked to increasing malnutrition, food insecurity, biodiversity loss and vulnerability of rural communities to climate change impacts, deforestation and monocultures continue to threaten habitats and natural recruitment capacities of these food trees. For instance, Uganda's natural forest cover has reduced from 12.1 million hectares in 1890 to 2.9 million hectare in 2012, with a significant effect on indigenous flora, being exacerbated by the emerging monocultures of eucalyptus, pine, and oil palm trees.

Upon this backdrop, this study seeks to evaluate and comparatively assess the social, cultural, ecological, and economic services/benefits of four food tree species: *Canarium schweinfurthii*; *Vangueria aciculoba*; *Pseudospondias microcarpa* (indigenous), and *Syzygium cumini* (naturalized) with the aim to promote their use in reforestation, afforestation and agroforestry systems of Uganda. This study is being undertaken in Lake Victoria crescent agro-ecological zone, involving a survey of 400 households and 40 in-depth interviews with farming households, foresters, forest experts and investors and local government leaders.

Results will establish the importance and multiple benefits of the investigated tree species for local livelihoods, human and animal nutrition, environmental conservation and climate protection. Conclusions drawn will refer to the possible conservation, domestication, and utilisation of these tree species in central rural Uganda.

**Keywords:** Agro-forestry, climate protection, deforestation, environmental conservation, livelihoods

## Could Ecological Importance Value of Wild Edible Fruit Trees Predict their Ethnobotanical Use Value in Protected Areas?

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In Benin, rural populations are highly dependent on non-timber forest products (NTFPs) for their food, feeds and incomes. The high use of some wild edible trees has led to their overexploitation by the populations even in natural forests which constitute the reservoir of wild edible trees. For this reason human pressure on wild edible species is ever increasing in protected areas, this stir up the need to assess the relationship between use value and ecological importance value of wild edible fruit species in the protected areas. An ethnobotanical survey with 136 respondents enabled assessing the use values (UV) of wild edible fruit trees. Following, the ecological importance values (IVI) of trees were estimated using the relative density, the frequency, and relative coverage of wild edible fruit species inventoried in 53 plots of 45m × 45 m installed in the Lama Reserve Forest. Thereafter, the relationship between these two values was estimated performing a simple linear regression analysis. Our study reported ten edible trees of which *Dialium guineense* had both, the highest use value and ecological importance value (UV=0.7 and IVI=1.424) while *Pterocarpus santalinoides* had the lowest value for both parameters (UV=0.0001 and IVI=0.003). Regression analysis showed significant positive relationship between use value and ecological importance value for edible fruit trees in the Lama Reserve Forest:  $UV = 0.362 IVI (R^2 = 0.42)$ , suggesting that wild edible fruit trees with multiple-uses had high ecological importance value. It is unexpected that a species with a high use value shows high ecological importance value, this observation made in the protected area of the Lama forest is an indication that riparian populations have limited access to the reserve. We recommend that same studies be repeated in other protected areas in Benin to confirm this correlation between use values and ecological importance values of wild edible fruit species. The species that had the highest use value should be introduced in plantation in the surrounding area of the Lama Forest, but also in agroforestry systems to take advantage of this endogenous conservation strategy that would enhance the conservation measures applied to the protected areas.

**Keywords:** Benin, ecological importance value, lama forest reserve, use value, wild edible fruit trees

## Multiplying Forest Garden Systems Financed by CO<sub>2</sub>-Subscription Schemes

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On abandoned, erosion prone terraces in the middle hills of Nepal, >200 participating farmer families planted 50,000 mixed trees in forest garden systems since 2015. All trees were planted with farmer-made organic biochar-based fertiliser. Planting pits were mulched with rice straw and were pipe irrigated from newly established water retention ponds during the 7 months of the first dry season after planting. A peer control system of farmer triads ensured an efficient maintenance of the plantations. Tree survival rate was above 80 % after one year. In between the young Cinnamon, Moringa, Mulberry, Lemon, Michelia, Paulownia, nut and other trees, secondary crops were cultivated such as ginger, turmeric, black beans, onions, lentils, all with organic biochar-based fertiliser and mulching.

The objective of this forest garden project was to establish robust social-agronomic systems that can be multiplied from village to village for increasing soil fertility, protecting abandoned terraces from erosion, replenishing natural water resources, generating a stable income with climate-smart agriculture, as well as capturing and sequestering atmospheric carbon.

The 50,000 mixed trees accumulate the equivalent of 700 t CO<sub>2</sub> per year (on a 10-year average). To monetize these carbon sequestration services, the project established a monthly CO<sub>2</sub>-subscription that creates a personal link between private GHG-emitter in Europe and the carbon sequestering farmers in Nepal. At 35 € per ton of CO<sub>2</sub>, the CO<sub>2</sub>-subscription covers the cost for the forest garden set-up and the carbon certification. Moreover, farmers receive carbon payments for each survived tree during the first three years. After this initial period of three years, the income from tree crops (fruits, nuts, medicine, essential oil, silk, perfume, honey, timber, animal fodder) exceeds by far the (catalyzer) carbon credits (average crop income for 10,000 trees including secondary mixed cropping > 70,000 Euro).

In our presentation, we will show and document the establishment of the forest garden systems, and discuss the link between local carbon sequestration and global carbon markets, the carbon calculation and certification procedures, and the challenge for multiplying such systems inter-regionally and internationally.

**Keywords:** Biochar based fertilisation, carbon credits, forest garden

## Water Productivity of Tree Wind Break Systems in Central Asia – Example Bazarkorgon, Kyrgyzstan

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Most of the agriculture in Central Asia depends on irrigation, e.g. agriculture in such areas like the Ferghana Valley or along other rivers in Central Asia. The major source of irrigation water are rivers. Glacier melt, snow melt, and rain fall in the mountains generate the runoff of those rivers. In the course of climate change, glaciers melt down so that a decrease in runoff by 20%-50% is expected by 2050.

Against this background it is of crucial importance to increase water productivity of irrigated agriculture and build resilience against water shortages. One method to achieve this goal might be introducing agroforestry, in particular shelterbelts. Literature suggests that crop evapotranspiration is reduced and crop yields are increased inside such shelterbelt systems compared to outside such systems. Though, changes of water consumption and income are unknown when farmers change add shelterbelts to their farm systems.

In order to understand those changes from a cropping system without shelterbelts to a agroforestry system with shelterbelts, water consumption of crops and trees as well as costs and benefits of crops and shelterbelt trees were assessed during the growing season 2017. The study area was a group of villages in the Ferghana Valley, Jalalabad Region, in Kyrgyzstan. Micro climate data were used in order to calculate crop water consumption. Tree water consumption was measured through sap-flow measurements. Costs and benefits attributed to crops and trees were revealed through farm interviews.

Results indicate that wind speed is significantly reduced by shelterbelts, which reduces crop water consumption inside a shelterbelt system. The overall water consumption of shelterbelt system was found to be lower by 5–15 % compared to non-shelterbelt systems. Income from shelterbelt trees added substantially to farm income so that the overall income from the crop-shelterbelt system was higher than income from the crop alone. This allows the conclusion that introduction of shelterbelts increases water productivity.

**Keywords:** Agroforestry, cotton, crop water consumption, fast growing trees, water productivity, wind breaks

## Farmers' Use and Preferences of Trees in Kurdistan Region of Iraq

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Trees play an important role in virtually all the natural ecosystems. Most of the trees have multiple uses, and they offer a range of valuable products such as fruits and service roles such as windbreaks, to the rural farmers and local people. The study aimed to identify the most important use of tree species by the farmers in Iraqi Kurdistan along with their preferences among the species as well as to evaluate the abundance of species. The methodology was based on the studies developed by World Agroforestry Centre (ICRAF) and International Service for National Agricultural Research (ISNAR) with appropriate modifications to the study conditions. The fieldwork was carried out in Erbil province of Iraqi Kurdistan from August until October 2017 in both lowland and highland areas. Altogether, 62 respondents were interviewed by semi-structured questionnaires and 46 tree species were identified in both regions. The results showed that fruit trees (grapes *Vitis vinifera*, olives - *Olea europaea*, pomegranate - *Punica granatum*, figs - *Ficus carica*, and apricots - *Prunus armeniaca*) are used extensively in both regions. Farmers relied mainly on fruit trees of various species due to high market profits and income generation. Besides that, farmers were generally focused on windbreaks as a service role in the lowlands. Regarding the species preferences, olives had a significantly high priority among the farmers in the lowlands, while the pomegranates were higher preferred in the highlands. Our study suggests, further development of agroforestry systems in Erbil could be an important factor in mitigating effects of climate change, especially in the case of increasing temperature. Better tree pruning and spacing may reduce the heat and thus save both fruit harvest quality and quantity. In the future, more studies should be conducted on farmers tree preferences and market value chains.

**Keywords:** Agroforestry, Erbil province, highland region, Iraqi Kurdistan, lowland region, sustainable development, tree priority, use of the tree

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## Research and Development in the Kyrgyz Walnut-Fruit Forests: Achievements and Lessons Learned for the Future

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The walnut-fruit forests of Kyrgyzstan are one of the centres of origin of many cultivated plants in Central Asia and a gene pool of global importance. Between 130–180 species of trees and shrubs alone have been found in these forests. In addition, they harbor many other, partially endemic, species of other classes and orders. At the same time, these forests provide numerous forest products and a source of livelihood to local populations. However, current patterns of forest management are unsustainable, vast parts of the forests are overaged, and derived benefits are unequally distributed among local populations. Because of their unique importance, the walnut-fruit forests and their sustainable management have been an object of scientific inquiry and a target of interventions by development projects alike. Significant academic work has been accomplished in studies of the biology, ecology, morphological diversity, the development of propagation methods, the protection of walnut and other nuts species from pests and forest diseases, and silvicultural and agroforestry research with a view to sustainably use the walnut forests. Development projects have focused on promoting sustainable forest management, participatory forms of resource governance, and the development of inclusive value chains for selected forest products. This paper presents the results of an extended analysis of secondary sources on the objectives, methods employed and results generated by previous academic research and largely donor-funded development projects in the walnut-fruit forests of Kyrgyzstan. It investigates how the activities of these projects have been sustained after project end given that many of these projects were of relatively short duration; how the project results were incorporated into management practice and which practical impact they had; and to which extent successor projects drew from previous works given that they were often funded by different organisations. The paper delineates two stages of research and development work that clearly appear from the analysis. It also presents the results of a stakeholder mapping of the various research and development organisations that are currently working on the sustainable utilisation of the walnut-fruit forest and identifies overlaps, blank spots and priorities for further research.

**Keywords:** Central Asia, Kyrgyzstan, sustainable forest management

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## Quality Parameters of Walnut (*Juglans regia*) Fruits from Kyrgyzstan as Affected by Abiotic Properties and Intraspecific Variability

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The Kyrgyz walnut-fruit forests harbor a huge natural diversity, including *Juglans regia* and other underutilised wild plant species. Even though many of these biological resources are traditionally used by the local community and have been scientifically described in terms of their diversity, their full nutritional potential has not been thoroughly investigated. Especially the relative influence of abiotic factors, such as climatic conditions or soil properties and the intraspecific variability is unknown. The present study therefore aims at evaluating the influence of soil properties and altitude on intraspecific variability of physical and biochemical quality parameters of walnut fruits. 375 fruit and 30 soil samples have been collected from a total of 3 randomly selected sample plots differing with regard to altitude levels and exposition. Soil samples from a depth of 0–30 cm and 30–60 cm were analysed for micro- and macronutrients, soil organic matter (SOM), carbonate content, pH and electrical conductivity. For walnut fruit samples nut weight, sphericity, shell integrity, shell diameter, nut crackability, weight and colour of kernels were examined. Additionally, fruit samples were analysed for water, ash, total phenolic and total antioxidant content of composite kernel samples. Furthermore, micro- and macronutrient content, total lipid and protein content, peroxide value, as well as fatty acid and amino acid profiles of kernels will be analysed and presented. First results indicate differences between the three sites in pH, SOM and carbonate content. Results that describe the strength and direction of the relationship between site factors and physical and biochemical fruit characteristics are being presented. Conclusions refer to implications for the sustainable management of the Kyrgyz walnut-fruit forests and the necessity of future research.

**Keywords:** Abiotic factors, intraspecific variability, Kyrgyz forests, quality parameters, walnuts

## Access to Genetic Resources and Fair Benefit Sharing under the Nagoya Protocol – Experiences of the BAOFOOD Research Project in Kenya

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According to the international Convention on Biological Diversity (CBD), the rights to biological resources belong to the state in whose territory they are found. The handling of these genetic resources is regulated in a binding international agreement known as the Nagoya protocol. The protocol was adopted in 2010 and entered into force in 2014. As of April 2018, it has been ratified by 105 member states. Each member state enacts detailed national legislation for the implementation of the protocol. In Kenya, users of genetic resources are obliged to comply and acquire permits from the implementing and enforcing government bodies of the Nagoya protocol including the Kenya Wildlife Service (KWS), National Environment Management Authority (NEMA), and Kenya Plant Health Inspectorate Service (KEPHIS). The permits require legally binding agreements with the communities in which the genetic resources exists and the specific government agencies, among them the Prior Informed Consent (PIC), the Mutually Agreed Terms (MAT), the Material Transfer Agreement (MTA), as well as the Benefit Sharing Agreement and Report on Utilisation. Using the case of the BAOFOOD project, the current paper presents the practical implications and challenges resulting from compliance with and acquisition of permits in line with the Nagoya protocol. The BAOFOOD project aims to promote the domestication, market development, processing and consumption of baobab (*Adansonia digitata*) for the improvement of food security, nutrition and rural livelihoods in Kenya and the Sudan, with the ultimate goal to establish a community-based processing unit to produce and supply highly nutritious baobab products. BAOFOOD is amongst the first projects in Kenya applying for permission under the protocol. The paper concludes that, while the larger objectives pursued with the enactment of the Nagoya protocol merit unreserved support, cumbersome procedures to implement existing regulations, unclear responsibilities at the national and local levels, lengthy processes involved in acquisition of the sequential permits, and a generally limited understanding of local authorities concerning the nature of non-commercial research projects have the potential to seriously affect the implementation of the research project. Successful references cases are therefore urgently required that could serve as guidance to local administrators and researchers alike.

**Keywords:** Bureaucracy, export of plant samples, international convention, research administration

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## Genetic Diversity of *Garcinia kola* (Heckel) in Southwest Cameroon

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*Garcinia kola* (Clusiaceae) is an indigenous fruit tree, originating in Western and Central Africa. It is a highly valued medicinal plant with all its parts being useful in traditional medicine. Especially the seeds are frequently used in Cameroon for treatment of a wide range of health problems (inflammation, liver cirrhosis, hepatitis, diarrhoea, headaches, etc.). Despite its frequent usage, the domestication process of this tree is at its beginning and throughout its distribution area, seeds are mostly harvested from the wild, which can lead to endangering of the species. Previous studies of *G. kola* have described the bioactive substances and nutritional content, however, information on genetic structure of existing populations crucial for domestication and conservation efforts of the species is lacking. The objective of this research was to analyse the genetic diversity of *G. kola* in Cameroon. 75 individuals from 4 populations were sampled in Southwest province of Cameroon and DNA was extracted from the seed coat. Twenty arbitrary RAPD primers were used for screening, and seven were chosen for final analysis based on polymorphism shown. PCR products were visualised on agarose gels and bands scored for presence or absence. A total number of 142 loci were obtained, with 136 of them polymorphic, showing 95.77 % polymorphism. The overall values of Nei's gene diversity and Shannon's diversity index ( $h=0.19$ ,  $I=0.32$ ) indicate high levels of genetic diversity in the sampled individuals. However, the index of Nei's genetic distance between populations reached very low values, showing lack of population structuring. Such values are quite typical for natural populations with low selection and domestication pressure. This study represents the first report to describe population genetics of *G. kola*. The results, together with morphological and biochemical data, can lead to better management and utilisation of *G. kola* genepool.

**Keywords:** Bitter cola, indigenous fruit, medicinal plants, population structure, RAPD

## Morphological Characterisation of Baobab Fruits from North and West Kordofan Provinces, Sudan

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*Adansonia digitata* L. (Malvaceae) is an iconic tree of the savannahs of sub-Saharan Africa. The edible fruit is known for its high nutritional values in pulp and seeds. The high morphological variability, particularly of fruits, offers a potential for domestication and development of improved materials. However, the variability in morphological fruit traits of Sudanese baobab has not yet been thoroughly documented. This study aimed at characterising the intra-specific diversity of baobab fruits collected from North and West Kordofan provinces, Sudan. Within the frame of the BAOFOOD project funded by the German BMEL, 93 trees were sampled from two transects (each 30 × 90 km) during two harvest seasons 2016–17 and 2017–18. From each tree, 10–20 representative fruits were collected and characterised based on the publication 'Descriptors for Baobab'.

Mean fruit length per accession ranged from 8.6 to 43.7 cm (total median 15.7 cm) and mean fruit weight from 46 to 403 g (median 128 g). Overall median pulp weight per fruit was 24 g (range 7–122 g per accession), while overall median pulp and seed proportions from whole fruit weight were 18 and 38 %, respectively. For 13 accessions we found a very high pulp proportion (22–30 %) and for 13 a very high seed proportion (46–53 %). Fruit shape was predominantly ellipsoid (51 %) with acute apex. Less frequent shapes were oblong-ellipsoid (10 %), oblong-globose (8 %) or oblong (6 %). Pulp taste, based on the four traits sweetness, sourness, bitterness and aroma, was highly variable, but 23 % of the sampled accessions had a sweet taste. Fruit length was positively correlated with fruit weight, pulp weight and pulp proportion ( $r=0.587^{***}$ ,  $r=0.672^{***}$  and  $r=0.450^{***}$ , respectively). Fruit length and weight as well as pulp weight and seed proportion were significantly higher in accessions from North as compared to West Kordofan, while pulp proportion did not differ. The morphological variability among our sampled accessions is substantial as expected; nevertheless, the morphological data will be further compared with genetic data. Our study shows that trees possessing highly valuable characteristics such as sweet pulp taste, big fruits, high pulp and lower seed content are available in Kordofan for future use in domestication programmes.

**Keywords:** Diversity, domestication, fruit length, pulp proportion, pulp taste

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## Assessment of Spatial Distribution and Population Health of Baobab (*Adansonia digitata*) in Kilifi and Kitui Counties, Kenya

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Baobab (*Adansonia digitata* L.) is a noteworthy African tree species with multiple uses. In Kenya, local communities in drylands mainly harvest the highly nutritious baobab fruits for home consumption and sale, which contribute to nutritional security and income particularly for women. The escalating international demand of baobab pulp may threaten baobab resources since the species is not domesticated. In Kenya, little is known on abundance and stand structures of baobab. Within the frame of the BAOFOOD project funded by the German BMEL, this study assessed baobab populations in randomly selected quadrats of  $0.5 \times 3$  km each along one transect from Mavueni to Mariakani (Kilifi County) and one from Kitui to Kibwezi (Kitui County), covering different agro-ecological zones. All baobabs within the quadrats were recorded by their position, height and diameter at breast height (DBH). Size class distribution (SCD) curves based on DBH were developed to assess population health. U-tests were performed to identify significant differences between the two transects. In total, 558 baobab trees were recorded in the 11 quadrats in Kilifi and 450 trees in the seven quadrats in Kitui (survey of further quadrats still ongoing). Median tree number per quadrat in Kilifi was 33 (range 9–140 per quadrat) and in Kitui 65 (range 20–133), resulting in median tree densities of 0.22 and 0.43 trees ha<sup>-1</sup>, respectively, with no significant differences between the regions. Median DBH per quadrat was similar (1.4 m) in Kilifi and Kitui, however, with high variability among quadrats and individual trees (maximum 4.97 m). Regarding the SCD curves, a higher total proportion of young trees (DBH < 100 cm) was found in Kitui (58 % of all trees) than in Kilifi (38 %) where, however, a higher proportion of old trees (DBH ≥ 200 cm) was recorded (24 %) as compared to Kitui (13 %). The surveyed area in Kitui shows therefore a more promising regenerating population but data to be collected from the remaining quadrats will give a more conclusive comparison of the tree populations in the two counties. Results of this study can contribute to develop more sustainable utilisation and conservation strategies of baobab in the two counties of Kenya.

**Keywords:** Conservation, diameter at breast height, size distribution, tree densities

## Fruit Morphological Diversity and Productivity of Baobab (*Adansonia digitata* L.) Trees from Kilifi County, Kenya

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Baobab (*Adansonia digitata* L.) is an indigenous wild fruit tree of great importance in African drylands due to its nutritional and health benefits and contributions to food security and income of local communities. In Kenya, however, the species' potential is not fully utilised and domestication could help in increasing its use. To select superior baobab mother trees for domestication, evaluation of phenotypic diversity is needed. This study aimed at assessing the variability in morphological fruit traits and productivity of baobab trees in Kilifi County, Kenya. Within the frame of the BAOFOOD project funded by the German BMEL, 33 fruiting baobab trees were studied along a transect from Mavueni to Mariakani in Kilifi County. All fruits per tree were counted and 10 fruits each collected for assessment of morphological characteristics including fruit shape, weight and length as well as proportions of pulp. Productivity per tree was calculated and correlation analyses between selected fruit traits were performed. There was high variation among the surveyed 33 trees in all measured productivity and morphological traits. Median fruit number per tree was 223 (range 118–309 per accession) resulting in a median productivity of 92.6 kg fruits per tree (range 26–160 kg tree<sup>-1</sup>). Median fruit length was 22 cm (range 18–49 cm), while median fruit weight was 376 g (range 220–696 g). Median pulp weight per fruit was 64 g (range 40–142 g), while median pulp proportion from whole fruit weight was 17 % (range 13–24 %). The most frequent fruit shape was ellipsoid (61 % of all accessions), followed by obovate (33 %). As expected, strong positive correlations were observed between fruit length and fruit weight ( $r=0.670^{***}$ ) and between fruit weight and pulp weight ( $r=0.844^{***}$ ), but not between fruit weight and pulp proportion ( $r=0.063$ , not significant). The large variations might be due to genotypic differences between the trees, but further fruit samples will be collected from Kitui area and analysed and latest results presented at the conference. The present study will contribute to select high yielding baobab mother trees with better fruit quality characteristics and will thus enable domestication and increased utilisation of this important indigenous fruit tree in Kenya.

**Keywords:** Domestication, fruit size, indigenous fruit tree, pulp proportion, superior mother tree

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## Optimum Oil Palm (*Elaeis guineensis* Jacq.) Planting Density for West Africa

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The African oil palm (*Elaeis guineensis* Jacq.) is the highest yielding oil crop and the major source of vegetable oil worldwide. As a perennial crop with a typical life cycle of 25 years, establishment costs are high but potential yields of up to 8 tons of oil per hectare can be achieved under favourable environments and with best agricultural practices making it one of the most profitable land-uses in the humid tropics.

Due to the radial symmetry of the foliage and their fasciculate root system, oil palms are typically planted in an equilateral triangle design. Spacing between palms determines planting density, a major contributor to oil yield. With a spacing that is too large, resources such as incident radiation are underutilised; on the other hand, too low a spacing excessive competition between palms will have a depressive effect on yield. As leaf mass and span increase over the first 12 years after planting, optimum density decreases with age. As a result of all these issues, the optimum planting density is the one that will achieve the highest cumulative yield over the 25 years cropping cycle.

This study presents the results from a 12 year old spacing trial in Nigeria. The highest cumulative yields per palm are recorded for the lowest density but the highest cumulative yield per hectare are still observed on the higher densities. However, the gap between both is shrinking with time as the competition for incident radiation increasingly affects the higher densities. While optimum density for cumulative yield at 12 years after planting is still 190 palms ha<sup>-1</sup>, extrapolation and simulation indicate an optimum between 143 and 160 palms ha<sup>-1</sup> over the entire cycle, corresponding to a spacing of 8.5 to 9 m.

**Keywords:** Nigeria, oil palm, planting density, West Africa



## Accuracy and Efficiency of Root Biomass Estimation Methods in Oil Palm (*Elaeis guineensis* Jacq.) Plantations

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Root biomass is one of the most used parameter to characterise root development and distribution within soil. However, different methods exist with regards to plant root system architecture, soil sampling volume and planting design but no standard protocol were set up for Monocotyledonous trees in an equilateral triangle planting design and comparing different ages of plantation. The purpose of this work was to identify the most efficient method to estimate root biomass for young and adult oil palm trees *in situ*. Three methods based on the sampling excavation volume were compared on the same sampled tree. Working time and manpower required for each operation were recorded. We compared two large excavation techniques based on the Voronoi tessellation procedure (full and half trench) with root auger coring method. Two industrial plantations of oil palm trees, of the same genetic material, aged 2- and 16-year old, were studied in Benin, West Africa. Oil palm root biomass was estimated to  $0.84 \pm 0.03 \text{ t.ha}^{-1}$  and  $22.23 \pm 0.81 \text{ t.ha}^{-1}$  for 2 and 16-year-old plantations, respectively. Even if no significant differences were found between simplified and full Voronoi trench methods for both plantations ( $p > 0.05$ ), root biomass were slightly overestimated (+ 4.8 %) and under-estimated (- 17.1 %) by the simplified Voronoi trench, when compared to full Voronoi trench method, for 2 and 16-year-old palms, respectively. However, a significant difference between simplified Voronoi method and auger method was found ( $p < 0.01$ ). Auger method underestimated the stock of oil palm root biomass of 2 and 16-year-old by (- 23 %) and (- 53 %), respectively. In terms of efficiency, auger method was the quickest, but underestimated twice, the amount of root biomass in adult oil palm plantation. Half and full Voronoi trench method need twice and thrice more time to perform respectively, but provided better root biomass estimates. Simplified Voronoi method is the most efficient method to estimate oil palm root biomass, especially at young age. Auger method was the least efficient at any oil palm age.

**Keywords:** Auger, root sampling methods, root typology, Voronoi trench

## Oil Palm Root System Characteristics in a 12 Year Old Density Trial in Nigeria

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Oil palm plantations have a typical economic life cycle of 25 years. As a monocotyledonous perennial crop the root system is radially distributed and shows no secondary growth but continuously expands. Oil palms are planted in an equilateral triangle design and the planting distance, determining the planting density, is fixed at the time of establishment. In time the roots from neighbouring palms will overlap and competition for soil resources can limit the growth and production of individual palms.

This paper presents the results from a root analysis study carried out on an oil palm density trial in Nigeria. The biomass and characteristics of the root system in an oil palm density trial have never been thoroughly studied so this would further the understanding of how planting distance affects underground processes in oil palm plantations for a particular environment.

The trial field was planted in 2005 following a Fisher block design with 6 treatments and 4 replicates. Plots consist of 72 palms of which the inner 20 are considered as useful (double row of border palms). The analysis was performed on 3 densities, D1, D3 and D6 corresponding to a planting distance of 9.5, 8.5 and 7.5 m and planting densities of 128, 160 and 205 palms ha<sup>-1</sup> respectively. A simplified voronoi method was used for the root analysis on one palm per plot. The voronoi volume was divided in 4 or 5 zones and 4 horizons giving 16 or 20 sampling volumes. For each of these volumes all the roots were removed and sorted in primary, secondary, fine and dead roots. Biomass for each was determined and extrapolated to a palm and plot level. Scanned images of the roots were also taken and analysed with WinRhizo to determine the root length, surface and volume.

**Keywords:** *Elaeis guineensis*, oil palm, planting density, root architecture, root system

## Let There Be Light: Light Interception Method Update for Oil Palm (*Elaeis Guineensis* Jacq.) Canopies

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Light interception (photosynthetically active radiation, PAR) experiments in oil palm (*Elaeis guineensis* Jacq.) plantations are scarce and often performed decennia ago, in Southeast Asia and without a clear methodology. This is a great opportunity for research with recent planting material in West-African growing conditions. Therefore a light interception experiment was performed in Nigeria. The first objective of this study was to put forward a recommendation regarding PAR interception assessment under oil palm canopies. Therefore a fixed and mobile PAR interception sampling method were compared. The second objective was to reveal PAR interception distribution under an oil palm canopy. In this study, PAR interception was monitored in oil palm plots of five different planting densities (128, 143, 160, 180 and 205 palms ha<sup>-1</sup>), eleven years after oil palm planting. During the fixed sampling, PAR was measured on sixteen equidistant locations below canopy with a quantum sensor (QS5 Quantum Sensor, Delta-T Devices). During mobile sampling, measurements were carried out by walking along two regular paths while holding the quantum sensor by hand. PAR above canopy was measured simultaneously during sampling below canopy. This study found no significant differences between the fixed and mobile PAR interception sampling methods ( $p > 0.99$ ), and this in the five different planting densities. Furthermore it was discovered that four regular fixed sampling locations below an oil palm canopy are sufficient for an exact assessment of PAR interception. This study showed also that PAR interception was randomly distributed under the canopy without a decreasing trend of PAR interception away from the oil palm trunk. Finally, there was no significant difference in PAR interception due to the shifting position of the sun between 10 a. m. and 2 p. m. ( $p > 0.78$ ). It is recommended to assess PAR interception with a fixed sampling method considering its ease, although data from both mobile and fixed methods are comparable. The standardisation of the fixed PAR interception method is easier due to the lower probability of human error compared to the mobile PAR interception method.

**Keywords:** Canopy, *Elaeis guineensis* Jacq., light interception, Nigeria, oil palm, PAR, photosynthetically active radiation, quantum sensor, West Africa

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## Impact of Topography on Oil Palm Yields in Marginal Conditions in Ghana

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Typically, Ghanaian oil palm plantations rest on an undulating topography. There is little information on how topography impacts on oil palm yields and growth. A study was conducted to evaluate this relationship in a commercial oil palm plantation located in the Kwaebibirem District of the Eastern Region of Ghana. The conditions under which oil palm is cultivated can be considered marginal because of inadequate mean annual rainfall (< 2000 mm) coupled with an uneven distribution. Also there is about 5 months of dry season coinciding with sometimes severe harmattan which can last for about 3 months. Soils here are generally not fertile, especially in replanted areas. The soil-relief and pests can also have great impact on the yields of oil palm. A plot with two different topographic positions – hillside and valley bottom – was selected for this trial. Three replicates were sited at each topographic position, making 6 replicates altogether. Four muriate of potash fertiliser treatments namely, 0.25 kg, 1.5 kg, 2.75 kg and 4 kg were applied per palm per year. Yields were recorded every two weeks for 6 years (from the 4<sup>th</sup> to the 9<sup>th</sup> year after planting). Foliar analysis was also conducted annually to monitor the leaf mineral nutrient levels. Results showed that average yield for the valley bottom/lowland was double that of the yield obtained from the hillside/upland. Hence, productivity of oil palm production can be greatly improved when cultivation is concentrated in the valley bottoms in these marginal areas. It is therefore proposed that a better land use, based on the maximisation of both the productivity of oil palm and sustainability of the whole cropping system be adopted. This land use proposal recommends a narrow band of natural vegetation around streams/rivers and creation of buffer zones to serve as catchment areas to prevent erosion and siltation. The slope will be reserved for rubber cultivation with biodiversity plots made of mostly local species occupying the summit of the hill.

**Keywords:** Hillside, topographic position, oil palm, valley bottom, yield

## Optimal Fertilisation for Oil Palm (*Elaeis guineensis* Jacq.) Plantations: Conclusions from a Long-Term Fertiliser Trial in Nigeria

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With a yield potential of more than 8 tons of oil per hectare the African oil palm (*Elaeis guineensis* Jacq.) is the most productive oil crop in the world. Since 2006, oil palm is the major global source of vegetable oil and production is expected to continuously increase by at least 2 % per year until 2050 (Byerlee et al., 2017). Oil palm cultivation is limited to the humid tropics where it is one of the most profitable land-uses despite the large investment costs of plantation establishment.

Fertilisation represents a major yield-impacting factor but is also the most costly input in the annual running cost of an oil palm plantation. As a perennial crop with a typical lifecycle of 25 years and a physiological lag effect of up to 3 years, it is essential to consistently optimise the fertilisation in the pursuit of high yields and greater sustainability.

This paper presents the results from a long-term factorial fertiliser trial in Nigeria comprising of 4 levels of potassium, 2 levels of magnesium and 2 levels of phosphor. The field was planted in 1997 with standard planting material for the region; the fertilisation protocol started in 2000 when the trees reached maturity. After 17 years of continuous implementation, a clear production response for K is observed which allows calculation of the economically optimal dosage. There are no significant effects from Mg and P, however. In addition, as a final conclusive study, the total standing biomass and its nutrient contents were also evaluated in 2018 and results presented.

**Keywords:** Biomass, fertilisation, Nigeria, nutrient content, oil palm, potassium

## Oil Palm (*Elaeis guineensis* Jacq.) Leaf K and Mg Contents Differ with Progenies: Implications and Research Needs

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Good management practice in oil palm rely on accurate predictions of fertiliser requirements that respect the environment and are economically optimal. A study performed in Indonesia pointed out that K and Mg leaf contents greatly vary from one oil palm progeny to another for the same production level. Such differences in nutrient contents may lead to an incorrect assessment of the nutrient requirements, questioning the validity of leaf analysis as a diagnostic tool and raise several research questions:

Do oil palm progenies with different leaf nutrient contents need to be fertilised with specific fertilisation tables? Does the difference in leaf nutrient contents between progenies reflect different patterns for nutrient allocation within plant tissues? Do mineral absorption and fertiliser recovery efficiency differ according to oil palm progenies? and to what extent so far? Is there any progeny which can adapt itself to agronomic practices requiring less fertiliser for highest production?

To answer these questions, a split plot trial has been set up and fertiliser was applied during seven years. It consisted of a factorial design, with 3-levels of K and Mg fertiliser respectively (KxMg) as main factor combined with 4-oil palm progenies (crosses having the same Dura and Pissifera origin) in subplots and 6-repetitions.

In the control treatment (K0Mg0), significant differences between progenies were observed. K leaf content of progeny-4 was 11 % higher than K leaf content of progeny-1 and progeny-2 and 35 % higher than K leaf content of progeny-3. This progeny-3 had the highest Mg leaf content, which was 24 % higher than that of progeny-2. All progenies responded differently to increasing K and Mg levels. Leaf K content increased with K levels for all progenies and significantly depressed leaf Mg contents. Mg leaf content of progeny-1 and progeny-4 increased with Mg levels but decreased in progeny-3 when progeny-2 didn't change. Also, after applying maximum dose of MOP, progeny-2 and progeny-3 K leaf contents were significantly lower than that of progeny-4 receiving nil MOP.

These results confirm the differences in foliar contents between the various oil palm genetic origins and thus of their contrasted foliar K and Mg mineral absorption spectrum.

**Keywords:** Leaf analysis, magnesium and foliar mineral signature, potassium, progenies

## Fine-Root Growth and Dynamic in Five Cocoa Production Systems Affect Biomass and Yield

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Competition for resources in mixed cropping systems is feared by the producers but may be accompanied by complementarities in resource use and other benefits resulting in trade-offs between the production goal and ecosystem services.

Cocoa is a tree with a shallow rooting system and often produced in association with shade trees. Rooting characteristics of these associated trees are often not known and depend on several factors like species composition and soil characteristics. We were interested in fine-root distribution and growth in five cocoa production systems, comprising monocultures and agroforestry systems, both under conventional and organic farming, and a successional agroforestry system. Therefore, we measured cocoa fine-root parameters at three distances from the cocoa stem in 10 cm depth and installed ingrowth-donuts to measure total fine-root growth increment over a twelve-month period in 0–25 and 25–50 cm depth. We compared fine-root data with aboveground performance of the five production systems, i.e., tree and herbaceous plants biomass, and the cocoa and whole system yield.

Cocoa fine-roots were homogenously distributed below the surface, only the mean fine-root diameter decreased with distance to the stem. Around 80 % of total fine-roots were located in the upper 25 cm. Total fine-root biomass increment was three times higher in agroforestry systems than in the conventional monoculture and the same was observed for the aboveground biomass. Cocoa yield was lower in agroforestry systems but additional crops make up a whole system yield that exceeds the reduced cocoa yield. Higher above- and belowground biomasses also refer to enhanced carbon sequestration in agroforestry systems. While fine-root growth in the organic monoculture was also three times higher than in the conventional monoculture, aboveground cocoa biomass and yield were lower. The soil in the organic monoculture was covered by a perennial leguminous crop that increased the herbaceous plant material tenfold to the conventional monoculture. This must be responsible for the high fine-root biomass and also for the lower cocoa performance due to competition with the cocoa roots.

In contrast to organic monocultures, agroforestry systems are suitable alternatives to conventional monocultures due to high system yield and biomass despite the reduced cocoa production.

**Keywords:** Organic, root biomass, system yield, *Theobroma cacao*

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## Sustainable Use of Resources: Soil and Water Management Practices on Cocoa Farms in Ecuador

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Cocoa (*Theobroma cacao* L.) is a cash crop produced by an estimated 5–6 million smallholder farmers globally. In Ecuador, as in other origin countries, the viability of production is threatened by climate change and already showing signs of being impacted by changing precipitation patterns, increasing temperatures, and more frequent occurrence of drought and flooding events. As cocoa is highly sensitive to water stress, the sustainability of future production will be determined by farmers' water use efficiency and management of soil and water resources. Ecuador is an interesting country case study offering key insights into the opportunities and challenges associated with cultivating fine-flavour and bulk cocoa varieties under water-limited conditions, and optimising water use, in cocoa-growing regions.

This study used a mixed methods approach to collecting qualitative and quantitative data in the provinces of Los Rios, Esmeraldas, Manabi, and Santa Domingo in Ecuador. A semi-structured household survey was administered to 70 smallholder cocoa farmers to evaluate the impact of climate change on production, and management of soil and water resources. Soil and water management practices were documented through observation and photography. Key informant interviews were held with cocoa sector stakeholders to elicit and triangulate data collected.

The study results reveal that smallholder farmers engaged in cocoa production in Ecuador are aware of the impact of climate change, and specifically, the impact of increasingly erratic and unpredictable rainfall patterns. Moreover, they recognise the need for adaptation and sustainable use and management of soil and water resources. Farmers are taking action to improve soil fertility and soil health, from the application of fertiliser based on soil analysis to reducing the use of herbicide and pesticide. Regarding water availability as the factor most influencing cocoa production and productivity, farmers are establishing small-scale irrigation systems, restoring water bodies (streams, pools), and establishing drainage systems and hillside terraces. Given the human, natural, and financial capital required to adopt new production practices, only those farmers who are willing, and in a position, to take risks are proactively looking to increase their resilience to climate change by adopting new and improved soil and water management practices.

**Keywords:** Climate change, management practices, soil, water



## Cocoa Agroforestry as Climate Change Adaptation Strategy in Ivory Coast: Scientist's versus Farmer's Perceptions

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Cocoa production in Ivory Coast is important for sustaining global supply, national economy and income of smallholder farmers but climate change poses a serious threat. Therefore, sustainable and resilient cocoa production systems are of crucial importance. Agroforestry is seen as an option to adapt the cocoa farming systems to projected changes of increase drought frequency and severity. However, there is ongoing scientific debate about the actual protective (microclimate moderation) and complementary resources (soil water and nutrients) use between shade trees and cocoa plants especially under drought conditions.

Objective of the study was to evaluate shade tree use intensity along precipitation gradient against the basic hypothesis that cocoa agroforestry practice increases with more challenging climate. Research was conducted on-farm in three climatically different regions classified by their annual precipitation as dry (1,000 mm), medium (1,500 mm), and wet (1,800 mm). Farms were characterised regarding shade tree species composition, shade cover, and plantation size. Farmers were interviewed about their recorded yield, farming practices and perception on shade and drought interaction.

Contrary to the expectations, the cocoa plantations showed no significant differences in yield, shade cover, cocoa tree density, and cocoa biomass across the climatic gradient. Yield median varied from 0.7 (wet) to 0.8 t ha<sup>-1</sup> (medium), shade cover median ranged from 10 (dry) to 17 % (medium), cocoa tree density median was between 1,100 (medium) to 1,400 trees ha<sup>-1</sup> (wet), and cocoa aboveground biomass median from 32 (wet) to 45 t ha<sup>-1</sup> (medium). The farmer interviews revealed a large difference in farmer's perceptions across the regions regarding drought mitigating effects of shade trees. While in the dry region shade trees were seen rather to have negative effects by 50 % of the farmers, in the medium and wet regions the shade trees were largely seen positive and a suitable adaptation measures against drought.

Farmers did not increase their shade tree use to adapt their cocoa farming systems in climatically less suitable region. In conclusion, the currently recommended agroforestry systems are not equally suitable along the climatic gradient of cocoa production in Ivory Coast.

**Keywords:** Agroforestry, climate adaptation, *Theobroma cacao*, West Africa

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# Soil and soil fertility

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## Unlocking Rice Potentials in Contrasting Wetlands in East Africa

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East African wetlands are increasingly considered a major asset to boost domestic rice production towards self-sufficiency as favourable edaphic and hydrological conditions support high production potentials. Hence, the identification of sustainable intensification options is crucial to maintain wetland resilience and ecosystem services. We studied the effects of hydrological condition and nutrient management on rice yields in both an inland valley swamp in Central Uganda and a floodplain wetland in South-West Tanzania between 2014 and 2017. Field experiments were established along hydrological gradients (cross-section of the wetlands), from the poorly-drained riparian, to the moderately-drained valley bottom/middle and the drought-prone fringe zones. Phenology, biomass accumulation and grain yield were monitored under different water and nitrogen management. Experimental data were subsequently used to calibrate and later validate the APSIM-ORYZA rice growth model. The study aimed at quantifying prevailing yield gaps and their explanatory causes as well as to test the models capability to simulate complex hydrological conditions and various genotype-by-environment-by-management interactions. Attainable (simulated) rice yields ranged between 5.0 to 7.0 t ha<sup>-1</sup> in Uganda, and between 8.1 to 9.8 t ha<sup>-1</sup> in Tanzania. In contrast, actual grain yields under farmer's management were significantly lower (Tukey  $\alpha = 0.05 < 0.001$ ) and varied between 1.3 and 2.7 t ha<sup>-1</sup> in Uganda and between 2.6 and 3.2 t ha<sup>-1</sup> in Tanzania. Consequently, maximum yield gaps amounted to 4.1 and to 5.8 t ha<sup>-1</sup> in Uganda and Tanzania, respectively. Spatial and temporal differences in soil moisture content differentially affected the grain yield in different hydrological positions in the wetlands. Therefore, daily measured soil moisture data is being used in the model to simulate the water balance and account for the differentiating soil moisture availabilities. The models capability to simulate rice growth and yield under complex hydrological conditions and with the effect of water- and nutrient limitations is being evaluated. Results will help to identify and understand main limiting factors and help developing sustainable cropping systems based on the positioning within the respective wetland.

**Keywords:** APSIM-ORYZA, *Oryza sativa*, Tanzania, Uganda, wetland, yield gaps

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## Combined Phosphorus and Water Management Options towards Sustainable Intensification of Rice Production in P-Deficient Lowlands of Sub-Saharan Africa

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In large parts of sub-Saharan Africa (SSA), rice (*Oryza* spp.) serves as an important staple crop. Population growth and urbanisation drastically increase rice consumption. Rice production should concomitantly increase to reduce dependence on rice imports, which endangers food security in many African countries.

Drought and low phosphorus (P) availability are two major abiotic constraints for lowland rice production in SSA. With increasing prevalence of water scarcity and the decline of phosphate reserves, it is urgent to develop sustainable solutions countering these limitations. Therefore, research towards the optimisation of management practices in P and/or drought prone lowland systems is needed to identify opportunities for improvement of resource use efficiencies and rice production.

Both water and P availability can influence root development in several ways. Understanding root plasticity under specific combinations of P and water management is important in efforts towards enhancing resilience to both stresses. There is an urgent need to investigate under which moisture conditions several P fertilisation techniques are applicable and it is important to understand the effects of management combinations on shoot and root development, before recommending them as sustainable intensification strategies.

In this study, several combinations of water saving technologies (i.e. alternate wetting and drying and permanent aerobic rice) and specific P fertilisation techniques (i.e. micro-dose placements and broadcasting) were tested in P deficient lowlands. Plant establishment, root development, yields, and fertiliser and water use efficiency were examined in order to identify best bet management options towards sustainable intensification of drought-prone and P-deficient rice growing lowlands.

Promising effects of P micro-dosing were observed under each water management scenario, but attention should be paid to counteract further P mining of the depleted soils. Root development was predominantly affected by water management. Rooting depth and lateral thickness increased under the water saving technologies, demonstrating that reduced water application can additionally enhance resilience and alleviate stress during drought periods. Reduced water application not only increases water productivity but also enhances the production when P is limiting. It is concluded that strategic combinations of P and water management can contribute to the intensification of rice production in P deficient lowlands.

**Keywords:** Lowland rice, phosphorus (P) fertilisation, P deficiency, water saving technologies

## Land Use Change Impact on Soil Organic Carbon: Insights from Isotopic Signature in Soil Profiles

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Soil is the largest carbon pool in terrestrial ecosystems, being the natural capital necessary to maintain soil fertility and food security. Land use changes in the tropics have been a large source of anthropogenic greenhouse gas emission and a threat for soil fertility loss due to intensive agricultural usage. Rubber expansion at the expense of tropical forest and shifting agriculture in Southeast Asia is one of those cases. Comparing soils under forest, rubber plantations and agricultural fields using so called “space substitute time” approach helps to assess the land use change impact on soil carbon stock. Isotopic signature of organic carbon in the soil profiles was analysed, aimed to assess the land use change impact and validity of applied method for comparing selected forest and land converted to rubber plantation.

We selected 3 group of sites in Xishuangbanna, Southwest China, each contained one forest plot and two (or three) rubber plots at different age, and sampled soils at 6 depths up to 90 cm with 15 cm sampling interval. The soil organic carbon content and stable isotope ratio of carbon-  $\delta^{13}\text{C}$  was determined for litter and soil samples.

Forest and rubber plantation had similar  $\delta^{13}\text{C}$  value in the litter, confirming that forest was dominated by C3 plants. The  $\delta^{13}\text{C}$  of soil increased with depth and stabilised below 30 cm, but its profile distribution distinctly differed between land uses and between sites. On two sites of three,  $\delta^{13}\text{C}$  in the forest subsoil below 30 cm were  $-23.3\text{‰}$   $-23.6\text{‰}$  and  $-24.4\text{‰}$   $-24.6\text{‰}$ , which were lower than corresponding values in rubber subsoil, suggesting that C4 crop, like maize or cassava preceded rubber plantation. In contrast,  $\delta^{13}\text{C}$  in forest and rubber subsoil was higher at the third site ( $-21.5\pm 0.1\text{‰}$ ), as compared to  $\delta^{13}\text{C}$  in forest subsoil from two sites mentioned above, indicating the previous cultivation of C4 crop in both forest and rubber plantation on the third site.

In conclusion, “space substitute time” method should be cautiously used in assessing land use change impact, adding historical land use information derived from  $\delta^{13}\text{C}$  signature in soil profiles can improve the validity of comparison.

**Keywords:** Delta  $^{13}\text{C}$ , forest, land use change, rubber plantation, soil organic carbon



## Feeding the Competitors – The Role of Heterotrophic N Immobilisation in Regulating Soil Nitrifier Activity

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Biological nitrification inhibition (BNI) has been conceptualised as a plant exerted regulation of soil nitrifier activity as a result of production and release of allelochemicals via the root. The tropical forage grass *Brachiaria humidicola* (Bh) has gained attention due to its remarkable BNI activity. Inconsistencies between the BNI ratings obtained by means of different methodological approaches led to the question whether low net nitrification rates solely originated in reduced gross nitrification rates or not rather in a plant facilitated heterotrophic microbial N consumption/immobilisation. Aim of the presented work was to determine which of both possible strategies would be the dominant under field conditions and under which edaphic environment Bh would most efficiently reduce net nitrification. For this purpose, a two-factorial pot trial with the factors “soil texture” and “Bh genotype” was conducted at CIAT headquarters (Cali, Colombia). Net nitrification rates were assessed via *in situ* monitoring of soil nitrate evolution using micro-suction cups. Growth response of both ammonia-oxidising archaea (AOA) and bacteria (AOB) to ammonium fertilisation was estimated by quantifying the respective *amoA* genes prior and 14 days after fertilisation. Microbial N immobilisation was calculated based on encountered microbial biomass N (*N<sub>mic</sub>*) before and 14 days after fertilisation. Soil texture revealed a significant influence on net nitrification rates ( $p < 0.05$ ) and nitrifier community abundances ( $p < 0.0001$ ), both increasing with clay content. AOA/AOB abundance confirmed the allelopathic activity of Bh with a strong tendency for reduced growth response of both nitrifying populations under the previously high BNI ranked genotype in all soils ( $p = 0.0532$ ). However, the observed suppression of nitrifier growth did not translate into lower but rather coincide with higher topsoil nitrate concentrations (net nitrification rates). As nitrifier growth response to N shall theoretically be a robust indicator for their metabolic activity, this discrepancy was mainly attributed to differences in subsequently immobilised nitrate by heterotrophic microbes. The latter hypothesis is currently being validated via respective *N<sub>mic</sub>* analysis. So far, it can be concluded that rather heterotrophic N immobilisation, but not allelopathic inhibition of nitrifiers is the major reason for low net nitrification rates encountered in Bh pastures.

**Keywords:** Allelopathy, biological nitrification inhibition, *Brachiaria humidicola*, intermicrobial competition, N cycle

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## Do We Need More Drought for Better Nutrition? – Water-Stress Effects on Nutrient Content of Food

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Plants are the main source of nutrients for humans, and in turn gather their nutrients from the soil. Soil properties and environmental factors such as weather determine the bioavailability of nutrients to plants, and consequently, to food. With increasing extreme weather events, sudden drought periods can affect plant growth, bioavailability of nutrients and quality of produced food. This study compared two regions in East Africa (Kapchorwa, Uganda and Busia, Kenya) that experienced drought during the second growing season in 2016. Thus, the main research questions were: (i) does drought have an impact on the nutrient composition of produced food; (ii) does drought affect crops differently when grown on soils of varying fertility?

A total of 127 maize grains (*Zea mays*) samples and paired soil samples were collected per region and season from randomly selected households during the long rain (March-August) (LRS) and the short rain (October-December) (SRS) seasons 2016. Crop and soil samples were analysed using a portable X-Ray Fluorescent Spectrometer (pXRF, Bruker) for magnesium, phosphorus, sulphur, potassium, calcium, manganese, iron, zinc, and copper. Soil properties including nitrogen, carbon, C:N, texture, pH, and eCEC were additionally measured.

Kapchorwa had a higher soil fertility compared to Busia. Additionally, nutrient concentration of monitored grains during the LRS were significantly higher in Kapchorwa than Busia. In both regions, yields decreased significantly between LRS and SRS due to drought. In Kapchorwa, maize grain showed a significant decrease in mean nutrient concentration of 42 % from the LRS to the SRS. In contrast, a significant increase in mean nutrient concentration of 41 % was observed in maize from Busia. The contradicting results were due to a complete cessation of rainfall in Kapchorwa before grain filling, whereas in Busia rainfall, although lower than in other years, ceased directly thereafter. The unexpected results of decreased nutrient concentration despite high fertility in Kapchorwa, compared to increased nutrient concentration with low fertility in Busia allude that extreme weather events have unpredictable effects on nutritional quality of food crops. There is need for further investigation to make best use of drought phenomena, to improve the nutritional value of crops.

**Keywords:** Drought, food composition, human nutrition, plant nutrition, water stress

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## Towards Nutritional Security through Agroecological Practices in Orange-Fleshed Sweetpotato Systems in Mozambique

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The introduction of orange-fleshed sweetpotato (OFSP) varieties in Mozambique is a successful food-based strategy to reduce malnutrition in rural communities. Specifically, due to its higher beta-carotene content, the precursor of vitamin A in the human body, and micronutrients such as zinc (Zn) and iron (Fe), the consumption of OFSP enhances the nutritional value of children's diets. To sustain sweetpotato production, large amounts of soil nitrogen (N) and potassium (K) are required. Thus, continuous cultivation without soil nutrient replenishment leads to soil degradation threatening a continuing food production. This issue is very important in limited-resource areas, where the lack of soil fertility management furthers soil degradation and food insecurity. Agroecological practices (i.e., intercropping, crop rotation, and fallow) that increase the diversity of agroecosystems can boost soil fertility and agricultural performance through increased nutrient supply.

This study investigated low and high plant diversity arrangements during three growing seasons in a field experiment conducted in Maputo, Mozambique. Four treatments in a range of low to high diversity arrangements were compared, respectively: (i) continuous OFSP monoculture, (ii) OFSP and mazie rotation, (iii) continuous OFSP-legume intercropping and (iv) OFSP-legume intercrop in a rotation with maize-legume intercrop.

We quantified soil N, K, phosphorus (P), Zn and Fe to identify if high diversity cropping system supply and preserve soil nutrients to sustain future cropping season. Additionally, we evaluated storage root yield and beta-carotene, starch, protein, Fe and Zn contents to determined if improved soil fertility can enhance nutritional quality of sweetpotato.

Our results show an increment in available K content after the first season in sweetpotato-legume intercrop. Storage root yield remained similar between treatments in each season. Sweetpotato-legume intercropping showed increased contents of starch and protein and the highest iron concentration after the third season, exhibiting the potential of higher diversity cropping systems to enhance nutritional quality of roots. Furthermore, we observed soil K accumulation in highly diverse systems revealing increased potential to supply nutrients for the following growing seasons.

**Keywords:** Agroecosystems, food security, soil fertility

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## Impacts of Land-use Change on Organic Carbon Storage in Highly Weathered Soils of Tropical Sub-Sahara Africa

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Land-use change of tropical forests for agricultural production is considered as a major cause for soil organic carbon (SOC) decline. However, the extent of land-use change impact on SOC storage is highly uncertain, especially for tropical Africa. Interactions with the soil mineral phase can modify such impacts because of high contents of pedogenic oxides and clay in these highly weathered soils and their potential for C stabilisation. The aim of the study was to determine land-use change impacts on SOC storage for soils commonly found in tropical sub-Sahara Africa. For that purpose ten pedological similar soils in the Eastern Usambara Mountains (Amani Nature Reserve, NE Tanzania) under contrasting land uses were sampled down to 100 cm soil depth. Measured SOC stocks were  $17.5 \text{ kg m}^{-2}$ ,  $16.8 \text{ kg m}^{-2}$ ,  $16.9 \text{ kg m}^{-2}$  and  $20.0 \text{ kg m}^{-2}$  for forests, tea plantations, croplands and home garden, respectively. A significant decrease in mean SOC storage of  $1.3 \text{ kg m}^{-2}$  was detected after changing forests into croplands for the 0–10 cm depth increment. No further significant land use impacts could be detected. All soils have a clay dominated texture and are characterised by high contents in pedogenetic oxides. No significant relationships could be detected between SOC and clay contents for the investigated soils. Statistically significant relationships were found between oxalate extractable Fe/Al and SOC contents for cropland soils only, although forest soils comprised a wider range of oxalate extractable Fe concentrations. Probably, a higher variability of fresh OC input in forests may obscure the relation between SOC and pedogenetic oxides under forests. Based on our preliminary results, the role of clay minerals and pedogenic oxides for SOC stabilisation and the related mechanisms as the formation of mineral-associated organic matter (MOA's) and aggregation will be further studied in these tropical soils. For that purpose a large field campaign was done in the same study area in spring 2018 again. We used X-ray fluorescence spectroscopy (XRF) to define a natural gradient in the pedogenic metal oxides and clay content.

The following hypotheses will be checked:

a) Increasing metal oxide and clay mineral content will result in larger amounts of

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SOM associated to the heavy fraction (HF), because of increasing availability of reactive surface groups.

b) Increasing availability of net-positively charged metal oxide surfaces will lead to a larger stabilisation of SOM by formation of MOA's,

c) Increasing ratios in metal oxides to clay minerals content will lead to larger amounts of water-stable aggregates and consequently to increasing storage and stabilisation of SOM within aggregates.

**Keywords:** Land-use change, kaolinite, pedogenic Fe- and Al-oxides, SOC stabilisation, SOC storage, Tanzania

## Development of Macronutrients in an Ugandan Inland Valley under Rice Production

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Soil degradation is one of the major problems in crop production. In combination with increasing population numbers this forces Ugandan smallholder farmers to produce their crops in the valley bottoms. Therefore, it is important to identify sustainable management options to maintain these areas in a healthy state.

Field experiments were conducted in an inland valley swamp in Central Uganda between 2014 and 2018 to study the effects of nitrogen and phosphorus addition (organic vs mineral) and water management on the availability of soil macronutrients. These were established in three positions crossing the valley bottom from the central channel (zone 3) to the fringe of the wetland (zone 1) with one zone in between (zone 2). Soil samples, taken from the topsoil (0–30 cm), were analysed for their carbon, nitrogen and Mehlich-3 extractable macronutrients (P, K, Mg, Ca). This Mehlich-3 solution allows the extraction of plant-available nutrients over a wide range of soil pH-values. First results of the first four seasons show that before the implementation of the experiment the variability of C, N, K, and Ca was highest in zone 3, close to the channel. There was no significant difference between all three zones. After the first harvest the C and N content of the soil decreased ( $3\text{--}10\text{ mg-C g}^{-1}$ ,  $<0.7\text{ mg-N g}^{-1}$ ) in all three zones, but the variability of these elements within each zone became smaller. After the first season the C and N content is increasing, with different amounts due to different management options. Available P is very low in all three zones ( $< 50\text{ mg-P kg}^{-1}$ ), but a slightly small impact of P-addition is recognisable in all three zones. There is no significant change in Ca and Mg in all three zones, whereas K keeps decreasing throughout the first four seasons in Zone 1, the fringe of the wetland.

**Keywords:** Carbon, Mehlich-3, nitrogen, Uganda, variability, wetland

## Soil Fertility Gradients in the Smallholder Cropping Systems in Limpopo Province, South Africa

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Maintaining soil fertility is key for the low input smallholder cropping systems in southern Africa. However, due to resource limitations, these farmers are often constrained to provide the necessary input to avoid nutrient mining. Hence, farmers tend to apply the available fertiliser in the nearby homestead fields, while the remote fields are typically neglected, causing a decline in soil fertility. Nevertheless, these patterns are known to be very site-specific (climate, inherent soil properties, socio-economic conditions). To verify this hypothesis, we assessed in smallholder systems of Limpopo, four distinct sites (Selwana, Gabaza, Tsiphuseni, and Mafarana). Only farmers (58) with both field types were assessed. In total, 116 soil samples were collected and analysed following the indicators of soil fertility. The differences between field types were evaluated across all sites by Tukey's test. The results indicated that, across all sites, the fields that are close to home have a conducive pH (6.0 – 7.5) while remote fields remained acidic (4.0 – 4.8). Furthermore, the mean available P and extractable Zn were also significantly higher on homestead fields (63.95 mg kg<sup>-1</sup> dry soil and 25.62 mg kg<sup>-1</sup>, respectively) and lower on distant fields (13.61 mg kg<sup>-1</sup> and 1.36 mg kg<sup>-1</sup> respectively). However, no significant differences were observed across all sites for SOC between homestead fields (0.97 %) and remote fields (0.98 %). Additionally, the mean extractable K was significantly higher on homesteads in Gabaza (573 mg kg<sup>-1</sup> against 99.1 mg kg<sup>-1</sup>) while the mean extractable Cu and Mn remained significantly lower on homesteads in Gabaza and Mafarana (9.22 mg kg<sup>-1</sup> against 11.16 mg kg<sup>-1</sup> for Cu and 14.33 mg kg<sup>-1</sup> against 22.46 mg kg<sup>-1</sup> for Mn). Soil fertility variability in smallholder systems of Limpopo can be explained by farmer's management practices that resulted in the allocation of nutrient resources on preferred fields. Consequently, soil fertility gradient patterns are true, and strongly observed for pH, available P, and extractable Zn. SOC, on the other hand, was found to be driven by the inherent soil properties – soil texture. This study suggested that soil fertility gradients should be considered when sustainable intensification pathways are discussed for the region.

**Keywords:** Organic carbon, smallholder systems, soil fertility gradients

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## **Linking Slopes to the Wetland: Water and Nutrient Fluxes in an Inland Valley in Uganda**

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Due to prolonged periods of water availability, wetlands are of increasing importance for agricultural production and hence for food security in East Africa. However, in inland valley wetlands crop performance and particularly the temporal and spatial dynamics of the fluxes of water and nutrients are likely to be effected by the land use on the slopes and attributes of the wider catchment. Thus, a deeper understanding of the physical processes that link valley slopes to the wetland is of crucial importance to ensure their sustainable management. Water fluxes from adjacent slopes act as carrier for nutrients, e.g. nitrate, which frequently limit crop growth for small-scale farmers with limited monetary resources. We investigated the spatial and temporal distribution and translocation of water and soil-born nitrate under three types of land use on the slope, namely bare land, semi-natural vegetation and patchy crop agriculture. Soil N content was monitored during four consecutive rainy seasons at different slope positions. Water fluxes from surface runoff and subsurface interflow were quantified in runoff plots on the slope and in excavations at the bottom of the slope. Slope water pathways in the soil were analysed using ERI (electrical resistivity imaging) and profile drillings.

Water was delivered to the wetland mainly through a sandy loam layer at the bottom of the slope. Nitrogen content in soil water differed between the three land use types and different slope positions, with highest concentrations found at the bottom of the slope and on the bare soil plots. However, nitrate loads in soil water of the wetland were very low. Thus downslope positions seem to be of special importance for an improved crop use of the nitrate being translocated along the valley slope, before it is lost under the anaerobic soil conditions of the wetland.

**Keywords:** Nitrate, run-off water, sub-surface water, watershed, wetlands



## Effect of Soil Management on Mite and Springtail Populations in Agroecosystems from Santa Clara, Cuba

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For assessing the effect of soil management on mites and springtails were selected twelve farms located on brown calcareous soil in Santa Clara, Cuba. Farms were grouped according to their soil practices and landownership, resulting in three groups: State farms run under conventional agriculture, private farms managed conventionally, and private farms organically managed. Besides, there were chosen three reference patterns (Pasture, Marabou and Natural), all under homogeneity edaphic and climatic. Two or three fields of each farm were selected for the study. Four composite soil samples per field were taken to 20 cm of depth. Sampling was done twice: November, 2015 and June, 2017 in order to study the dry and the rainy season. The analyses of mites and springtails were done by the Bayer's methodology (2006). For the extraction of the mesofauna components, 300 g of soil were placed in modified Berlese funnels, which separated the organisms from the soil by entrapping them in alcohol. Generally, mites and springtail populations are lower in soils under agriculture. In both seasons, the higher number of mites and springtails were found in the marabou and in the natural forest, without difference with the pasture area. The farms under organic management showed populations lower than these references areas, but higher and significantly different from those farms under conventional agriculture. No significant differences were found between the fields under conventional farming, either from the private or state sectors. It can be assumed that the organic management diminished the negative effect of agriculture on soil mesofauna. The structure of the mites' community showed that Oribatid was the most abundant order and never was below 60 %, followed by Mesostigmata and Gasamids. The Prostigmatide was the order with low populations. In the springtails' group, the family Isotomidae presented the highest number of individuals and the lower was found in the family Entomobryidae. These results suggest that the effect of soil management in agricultural systems showed influence on soil mesofauna component used as indicators for determine soil health.

**Keywords:** Farming systems, mesofauna, mites, soil management, springtails

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## Performance Evaluation of the Irrigation System in Lower Kabul River Basin, Afghanistan

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The agriculture sector is the backbone of Afghanistan's economy and makes up around 22% of its GDP. Wheat is the main staple food of the country and accounts for over half of the population's caloric intake. Because of the complex terrain of the country, crops are cultivated on only about 12% of the total area out of which 70 % is solely occupied by wheat crop. Being a cereal deficit country, Afghanistan depends on food imports from neighboring countries to meet the growing population's food demand; the reason behind insufficient food production is the poor land and water productivity of the conventional farming system across the country. As a physical water scarce country, the insufficient rainfall does not meet the local crop water demand. The growing water scarcity problems in the region have not only limited the availability of water for existing agriculture but have also partly restricted the expansion of irrigated land. Prior to any irrigation water management and development initiative to be taken, it is vital to evaluate the existing situation of the on-farm irrigation system of the Kabul River Basin (KRB). Through this study we assessed the irrigation performance by using irrigation application efficiency as the key indicator under the conventional irrigation system in the lower reaches of the KRB. For this purpose, Attawor irrigation scheme, located at the downstream KRB, was selected where winter wheat was grown. Throughout the wheat growth period, a total of 6 irrigation events were applied and measured. Soil moisture content (%) before and after each irrigation event was measured in order to analyse the amount of irrigation water applied against the demand (i.e. irrigation application efficiency). Results of the on-farm experiments showed that the average irrigation application efficiency at field-level was 46 % while the overall range was 34-74 % depending on the canal water availability at different crop growth stages. The existing irrigation application in the study area shows that there is potential for water saving within the irrigation networks provided some technological interventions, infrastructural development and social awareness.

**Keywords:** Afghanistan water, food security, irrigation system evaluation, Kabul river basin, water scarcity

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## Residual Nitrogen Effect of Mungbean (*Vigna radiata*): Affected by Regulated Deficit Irrigation?

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Dryland areas in South and Central Asia are experiencing low agricultural yields and food scarcity under growing conditions with severe water shortages, heat stress, and limited arable land due to saline soils. Mungbean (*Vigna radiata*) is gaining attention as a short-season crop, tolerating dryland conditions, fixing atmospheric nitrogen (N) and hence decreasing soil nutrient depletion. It is a source of high-quality protein for human consumption and could serve as a multipurpose crop if residues were used as fodder or green manure. However, using pulses for N input in cropping systems requires improvements in the accuracy to estimate N balances and N benefits for following crops, since grain and above-ground residues are removed at harvest. Moreover, the effect of drought on N translocation within the plant is unclear. This work aims to quantify N accumulation, N partitioning between above- and belowground parts by mungbean accessions when influenced by water stress, the effect of drought on mungbean residue decomposition, soil microbial activity and N input to the soil.

In 2016 and 2017, two greenhouse pot experiments were conducted at the University of Hohenheim investigating potential adaptive strategies, N translocation in the plant and biological N fixation of four mungbean varieties under three levels of regulated deficit irrigation (RDI) with increasing degrees of water stress (45, 65, and 80 % deficits of available water capacity). Differences in the response to drought stress between the accessions were determined by stable isotope analysis. Additionally mungbean residues incorporated in potted soil were exposed to the same RDI treatments in a third trial in 2018 to assess the effect of drought on decomposition of the plant material, microbial activity and N release.

The results indicated that around 20 % of the total mungbean biomass is allocated belowground, accumulating 6–9 % of the total plant-N and 12–17 % of total plant-C, being not significantly affected by drought, but by variety. Moreover, a higher water deficit inhibited the activity of microorganisms and resulted in a slower N release, contributing to a higher N availability in the soil for subsequent crops when rewatered. This indicates an unexpected potential of new mungbean varieties for drylands.

**Keywords:** Deficit irrigation, nitrogen partitioning, residual effect, stable isotopes, *Vigna radiata*, water stress

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## Soil Rehabilitation Potential of Co-Compost Pellets Made from Municipal Solid Waste and Dewatered Faecal Sludge as Feedstock

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Solid waste management challenges are felt most keenly in the developing countries as a major consequence of development and modernisation. Sri Lanka as a developing country faces severe issues in managing the daily generated liquid and solid waste. Organic fractions of these waste takes a higher percentage. The organic portions of municipal solid waste (MSW) and co-composting of dewatered faecal sludge (DFS) is a feasible low-cost technology which enhances sanitation and waste management. The aim of this research was to evaluate the effect of MSW and DFS co-compost pellets produced with the addition of mineral fertiliser and biochar on soil chemical and biological properties. Trapezoidal windrow type co-compost piles were prepared with 18m<sup>3</sup> volume and 70 % MSW and 30 % DFS. Temperature measurements, watering and turning were done as necessary. Weekly samples were collected for chemical analysis. Resulted co-compost was mechanically pelletized using biochar and mineral fertiliser as additives and used in maize cultivation. The experiment was arranged as randomised complete block design using 7 treatments. Soil samples were collected from 30cm and 60cm depths to evaluate chemical and biological properties. There was a significant increase in pH values between control treatment (mineral fertiliser) and MWS-DFS co-compost treatments. The treatment with DFS-MSW-Biochar had the highest EC and organic carbon value suggesting that biochar has the ability to increase EC in soil and act as a carbon sequester. MSW-DFS co-compost treatments had the highest phosphorous and potassium values. Soil microbial activity was not significantly changed with the application of co-compost. Further, temperature changes during the co-composting process, was different from normal composting process, which may be resulted in a variation in feedstock characters. These results conclude that co-compost help to improve soil pH, EC, organic carbon, phosphorous and potassium with compared to the mineral fertiliser application. Hence, co-compost produced from MSW and DFS can potentially be used in soil rehabilitation while co-compost enriched with biochar act as a soil amendment.

**Keywords:** Biochar, co-compost, dewatered faecal sludge, municipal solid waste

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## Effect of Plastic Mulch and Anti-Transpiration Materials on Yield, Yield Components and Water Use Efficiency of Rainbow Corn (*Zea mays* var. *indurata*) under Different Irrigation Regimes

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In order to investigate the effect of plastic mulch and anti-transpiration materials on yield, yield components and water use efficiency of rainbow corn (*Zea mays* var. *indurata*) under different irrigation regimes, an experiment was carried out as split-split plot based on a randomized complete block design with three replicates at Marvdasht city of Farce Province during the two successive seasons 2016 and 2017. The irrigation regimes (irrigation after 25, 40 and 60 % of field capacity water depletion) were consisted as the main plots and two levels plastic mulch (with and without mulch) were allocated to the sub-plots. Three levels anti-transpiration materials (kaolin, atrazine and no material) were consisted as the sub-sub plots. Irrigation regimes were applied based on field capacity water depletion at the depth of root development. To achieve these irrigation levels, soil moisture was calculated by weighting method through a frequent and daily soil at the depth of root development. At irrigation regime of 25 % of FC water depletion, the highest fresh ear yield ( $1629.1 \text{ g m}^{-2}$ ) was found when soil surface was covered with plastic mulch and plants were sprayed with atrazine. On the other hand, the minimum fresh ear yield ( $1026.4 \text{ g m}^{-2}$ ) was obtained when soil surface left uncovered and no anti-transpiration materials were applied. With decreasing of soil moisture, the application of atrazine compared with kaolin resulted in increased fresh ear yield. When irrigation was applied after 60% of field capacity water depletion, the highest harvest index (53 %) was obtained in the plastic mulch treatment and non-anti-transpiration treatment. The maintenance of moisture under the plastic mulch increased harvest index compared with the uncovered soil surface. At irrigation regime of 60 % of field capacity water depletion, the highest water use efficiency ( $2.83 \text{ kg m}^{-3}$ ) was related to those plots which were covered with plastic mulch and treated with atrazine. According to the results, application of plastic mulch and atrazine as an anti-transpiration material could increase crop yield and water use efficiency in regions where water is the main limiting factor.

**Keywords:** 1000 grain weight, ear yield, evapotranspiration, kaolin, rainbow corn, water consumption

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## Determination of Brachialactone Release Mechanism in *B. humidicola* by Root Exudate Profiling under Different Elicitors

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The ability of plants to suppress soil nitrification through the release of nitrification inhibitors from the roots is termed ‘biological nitrification inhibition’ (BNI). The tropical forage grass *Brachiaria humidicola* (Bh) has particularly caught attention in this respect due to its ability to release a root exudate termed “brachialactone” that deters both ammonia monooxygenase (AMO) and hydroxylamine oxidoreductase (HAO) enzymatic pathways in nitrifying organisms such as *Nitrosomonas europaea*. What remains unknown is if brachialactone is exuded in the rhizosphere via an active, regulated transport or through passive release mechanisms (diffusion / root turnover). Taking this as a starting point, we studied the exudation pattern of brachialactone in hydroponically grown Bh under the effect of contrasting nutritional nitrogen forms and different pH regimes. Contrary to the previous hydroponic studies, exudation patterns were studied in the full nutrient trap solutions and plants were exposed to the exudate collection solution for only 4 hours. Through this approach we have minimised the plasma membrane damage due to osmotic stress or pH shifts to the greatest possible extent. The trial included six treatment combinations with three different nitrogen sources (i.e. ammonium & nitrate, sole ammonium and sole nitrate) and two levels of pH (i.e. 4.8 and 6). Subsequent to root exudate collection, trap solutions were analysed for brachialactone, ammonium/nitrate levels, sugars, amino acids and carboxylates. To elucidate whether brachialactone is released by means of a regulated process, i.e. demonstrates a unique response to the different treatment combinations, its exudation levels were compared to the exudation levels of major primary metabolites. Our study confirmed that the nutritional N form has a significant effect on brachialactone exudation ( $p = 0.0001$ ) and pH has a synergistic effect on its release ( $p = 0.0417$ ). We have found that brachialactone exudation is correlated with ammonium uptake but does not seem to be linked to the exudation of any of the other primary metabolites.

**Keywords:** Biological nitrification inhibition, brachialactone, primary metabolites, release mechanism, root exudate profiling

## How Residues of Differently Aged *Calliandra calothyrsus* Shape the Abundance of Soil Nitrifying Prokaryotes

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The use of leguminous organic residues in resource-prone smallholder farming systems is widely acknowledged. A central knowledge gap remains, however, to what extent a change of biochemical quality (e.g. C/N ratio, ([polyphenol+lignin]/N (PP+L/N) ratio) of organic inputs as result of increasing age of the same plant species shapes the abundance of soil nitrifying microbes (i.e. ammonia-oxidising bacteria (AOB) and archaea (AOA)). The aim was thus to assess age effect reflected in differences in biochemical quality of organic inputs, on the abundance of amoA gene copies (AOA and AOB) during the initial stages of decomposition. Organic inputs from leguminous *Calliandra calothyrsus* (10 ton ha<sup>-1</sup> dry weight) of different age (i.e. <3 years; C/N ratio 13.1; PP+L/N: 2.95, >5 years; 18.2, 3.02) were mixed with two soils from Ethiopia (pH 4.3; TC 2.32; TN 0.15) and DR Congo (pH 5.1; TC 3.52; TN 0.29). A control treatment without residues was included. Soil samples were obtained at 7, 15, 30, 45 and 60 days after residue application. Samples were analysed for amoA gene copies for AOA and AOB as well as for total bacterial and archaeal 16S rRNA gene copies using quantitative PCR. Generally, under the young *Calliandra*, increasing of gene copy numbers ( $p < 0.001$ ) of AOA and AOB ( $p < 0.01$ ) were observed. Input type and incubation time showed a significant interaction for AOB abundance ( $p < 0.01$ ), which increased from day 7 to 45. N-NO<sub>3</sub>, NH<sub>4</sub><sup>+</sup> and DON concentration was correlated with AOA ( $r=0.76$ ,  $p < 0.0001$ ;  $r=0.42$ ,  $p < 0.0001$ ;  $r=0.75$ ,  $p < 0.0001$  respectively), and AOB ( $r=0.58$ ,  $p < 0.0001$   $r=0.25$ ,  $p < 0.01$ ;  $r=0.57$ ,  $p < 0.0001$ ) abundance throughout the incubation. The study demonstrated that the abundance of nitrifying prokaryotes was influenced by biochemical quality of residues obtained from differently aged *Calliandra*, which was mainly attributed to the increase in amoA gene copies of AOA and AOB under young *Calliandra*, a phenomenon that may be explained by the low C/N and PP+L-N ratios. Results showed that the assessed change of biochemical quality of organic inputs is a determinant of the abundance of soil nitrifying microbes and has to be considered when using contrasting organic residues for adapted soil fertility management in resource-prone smallholder agricultural systems.

**Keywords:** 16S Archaea, 16S Bacteria, AOA, AOB, residue quality

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## Coffee Husk Biochar Application Improved Soil Chemical Properties and Yield of Soybean Grown in a Tropical Nitisol, Ethiopia

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Low levels of soil fertility and soil acidity are among the major bottlenecks to enhance agricultural productivity in the humid tropics. Soil management systems that enhance soil fertility and biological cycling of nutrients is crucial to sustain soil productivity. This study was, therefore, conducted to determine the effects of coffee husk biochar (here after biochar), *rhizobium* inoculation and P fertiliser application on Arbuscular mycorrhizal fungi (AMF) root colonisation, yield, P uptake and N<sub>2</sub> fixation of soybean grown on tropical Nitisol of Jimma, southwest Ethiopia. The experiment consisted of two levels of *rhizobium* inoculation (with and without), phosphorous (P) application (0 and 20 kg ha<sup>-1</sup>) and four levels of biochar (0, 6, 12 and 36 t ha<sup>-1</sup>) in a 2 × 2 × 4 factorial design with 3 replications. The experiment was conducted under lath house conditions in 2015. ANOVA showed that integrated application of biochar and P fertiliser significantly improved soil chemical properties, P uptake and seed yield, with a seed yield increment of more than two-fold and highest total P uptake (4.5 g plant<sup>-1</sup>) with inoculation, 20 kg P and 36 t biochar compared to the yield from the control (without inoculation, P and biochar). However, the highest AMF root colonisation (80 %) was obtained at 36 t biochar without P and declined with 20 kg P application. The highest total N content (4.2 g plant<sup>-1</sup>) and N<sub>2</sub>-fixed (4.6 g plant<sup>-1</sup>) was obtained with inoculation, 20 kg P and 36 t biochar. However, the highest %N derived from the atmosphere (%Ndfa) (>98 %) did not significantly vary between 12 and 36 t biochar treatments at each level of inoculation and P addition. The improved soil chemical properties, seed yield, P uptake and N<sub>2</sub>-fixation through combined use of biochar and P fertiliser suggests the importance of integrated use of biochar with P fertiliser to ensure that soybean crops are adequately supplied with P for nodulation and N<sub>2</sub>-fixation in tropical acid soils for sustainable soybean production in the long term.

**Keywords:** Acid soil, AMF, biochar, N fixation, soybean



## Mercury-Resistant Bacteria Isolated from Mercury-Contaminated Site near Rice Field

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Several traditional gold minings in North Sulawesi, Indonesia, discharge tailings containing mercury to nearby rice fields. Rainwater can carry mercury waste to the rice fields, contaminate the soil, and accumulate the mercury in the rice plants. Given the situation, it is deemed necessary to develop remediation approaches at mercury contaminated sites.

This research was aimed at isolation and identification of mercury-resistant bacteria from traditional mining site in North Sulawesi and analysing their ability to reduce mercury chloride (HgCl<sub>2</sub>).

The bacterial isolates (AA, BB, and DD) were isolated from soil samples obtained from three mining waste location points by growing them in LB media containing 40 ppm HgCl<sub>2</sub>. Discrete bacterial colonies were isolated and identified conventionally by morphology, physiology and biochemistry test of H<sub>2</sub>S formation, carbohydrate fermentation test, citrate test, lysine test, indole test and catalase test and molecularly using 16S rRNA gene marker. The ability of bacteria to reduce of 40 ppm HgCl<sub>2</sub> was evaluated. Analysis of mercury concentration in the medium was carried out using the cooling vapour atomic absorption spectroscopy (CV-AAS)

The results showed that there were 3 bacterial isolates from all three samples can grow in LB broth medium with 40 ppm HgCl<sub>2</sub>. Biochemical identification showed that all the isolates belong to *Pseudomonas* genera. Using 16S rRNA, isolates AA and DD showed high similarity with *P. plecoglossicida* and BB with *P. aeruginosa*. All isolates reduced almost 100 % of HgCl<sub>2</sub> within 24 hours.

All three bacterial isolates AA, BB and DD showed potential to be used for remediation of mercury waste.

**Keywords:** Mercury waste, mercury-resistant bacteria, remediation

## Implementation, Monitoring and Management of a Pilot Rehabilitation Measure on Degraded Sloped Pastures in Brazil

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Dairy cattle farming at moderately to strongly inclined pasture slopes represent the main land use in the State of Rio de Janeiro, occupying more than 50 % of the States area, formerly covered by pristine Atlantic Forest areas. Inappropriate pasture management in a geo-ecologically sensitive environment with changing regional climate has led to severe pasture degradation during the last century. Sustainable and adequate pasture management strategies are urgently needed to decelerate further soil degradation and to guarantee future land productivity while maintaining essential ecosystem services. The pilot rehabilitation measure (PRM) “Slope parcelling hedgerow terraces for extensive rotational pastures” aims at breaking the erosive power of surface runoff and interflow, accelerating grass recovery and decelerating erosion along with site-compatible rotational cattle management. It is embedded in the overall concept of relocating extensively-used pastures from fragile sloped to favourable, productive and intensively-managed plain areas. The PRM represents a pragmatic and participative (farmer-oriented) approach, at rather low cost. Its modular character allows a site-specific implementation (transferability) and adaptation that integrates existing resources and (traditional) farming best practices. Only scientifically proven measures accepted by the farmer community are supposed to be successfully applied and managed over a long time. Besides bio-engineering aspects of the implementation (terrace construction, planting scheme of various native tree-species, irrigation concept, pasture melioration) and recommended management strategies of the PRM, a two year scientific monitoring of the pilot area (shrub performance on terraces, closure of vegetation cover, soil quality and erosion) is presented. The latter allows the evaluation of the measures’ success and impact. The PRM will be discussed in the context of other vegetative and structural pasture rehabilitation approaches.

**Keywords:** Bio-engineering, degradation, pilot rehabilitation measure, rural area, sloped pasture

## The Effect of Prometryn Soil Residue on Soil Microbial Biomass and Different Crops Biomass

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The environmental risk of herbicides should be evaluated near sites of use, even though basic ecotoxicological tests have been conducted before they can be registered for marketing. For example, triazine herbicides, which are photosynthetic PSII herbicides are considered only slightly or moderately toxic for soil microorganisms, mammals and humans. However, concerns have arisen because these herbicides are members of a class claimed to be carcinogenic, or may affect the development of reproductive toxins. For this reason, more reliable evidence is needed to test these claims and investigate their ecological effects. Prometryn is a triazine herbicide that may leave residual activity in the soil for extended periods, causing injury of susceptible soil microorganisms and yield reduction of crops in rotation. A pot experiment was conducted under greenhouse conditions in order to study the sensitivity of 4 different crops (lettuce, barley, rapeseed and beet) to prometryn soil residue (0.0033, 0.0166, 0.033, 0.066, 0.1 and 0.166 mg kg<sup>-1</sup>soil) in Iran, 2014. The plants were thinned to five plants per pot after germination. The pots were kept for 30 days under controlled conditions. Shoot and root biomass production was measured 30 days after emergence. Results showed that the shoot and root dry matter were significantly affected by increasing prometryn soil residue in all crops ( $p < 0.01$ ), but seed emergency was not affected. Crops showed different responses to prometryn soil residues. Based on ED50 parameter rapeseed (0.0137 mg kg<sup>-1</sup>soil) and barley (0.0282 mg kg<sup>-1</sup>soil) appeared the most sensitive and tolerant crops to prometryn soil residue, respectively. Overall crop sensitivity to prometryn soil residue was: rapeseed>lettuce>beet>barley. Based on the mechanism of action of prometryn and its best efficiency on broad leaf plants control, the least biomass reduction obtained for barley is understandable. It means Prometryn is more efficient on dicotyledons, so barley as a monocotyledon crop will be tolerable to this herbicide and its biomass reduction will be low. In general, it is safe to plant a susceptible species if the plant-available residue is less than the species ED10 value, and there would be a great risk of crop damage if the plant-available residue is higher than ED50 values of the species.

**Keywords:** ED50, microorganism, persistence, rapeseed, triazine

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## A 3D Mixed Model for Soil Organic Carbon Mapping in Mountainous Subtropics

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The need to increase agricultural production leads to rapidly changing landscapes in mountainous South East Asia. As changing soil organic carbon (SOC) concentrations and stocks are a strong indicator for potential soil fertility loss, there is a need to quantify them with high resolution at landscape level. With 3D modelling, soil properties distribution across soil depth and in space can be predicted in one single model. Mixed models can be used in 3D digital soil mapping and especially suitable for upscaling, which we demonstrate with the new “mixed model over continuous depth” (MMCD). Soil sampling at 120 locations to 1 m depth was done in a 43-km<sup>2</sup> study area in southwest China using an optimised sampling design: cost-constrained conditioned Latin hypercube sampling (CCLHS). The MMCD was used for SOC concentration and SOC density mapping. It showed that SOC was strongly linked to an interaction of elevation with mean horizon depth ( $p < 0.001$ ) and to the land use type ( $p < 0.001$ ). The MMCD was compared to several mapping approaches, including a 2D and two different 3D kriging with external drift approaches and depth interval-based multiple linear regressions. The MMCD proofed to be as powerful as these established techniques, with an overall modelling efficiency (EF) of 0.72. All tested models strongly decreased in accuracy with depth (EF 0.8 in topsoil to 0.2 in deepest subsoil). The MMCD was further used to model highly unbalanced SOC density data with 120 topsoil observations and only 11 locations with subsoil observations (EF of 0.75). Computed prediction intervals (95 %) accurately covered the range of legacy measurements. We found that essential parts of soil carbon were stored in subsoil in this region. On average, 15 and 10 % of SOC stocks are expected in the 60 to 80 cm and 80 to 100 cm soil depth intervals, respectively. The combination of applied sampling scheme (CCLHS) and the new model (MMCD) is particularly suitable for mountainous subtropical areas with poor road networks, given that strong relationships of the soil property of interest with explanatory environmental covariates exist.

**Keywords:** 3D digital soil mapping, mixed model, SOC stocks, upscaling

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## Diffuse Reflectance Fourier Transform Mid-Infrared Spectroscopy Associated with Peak Area Integration to Predict Soil Carbonate

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Soil carbonate is a key component in agricultural soil influencing fertility and productivity. But its determination has need of using labour intensive and expensive traditional approaches. Diffuse reflectance infrared Fourier transform spectroscopy in mid-range (midDRIFTS) has with various degrees of success been used to determine different soil properties. This study evaluated the feasibility of using two different spectroscopic-based approaches, integrated peak area (IPA) & independent calibration (IC), to predict soil carbonate. The specific peak area (PA) as an indicator of soil carbonate and composition [e.g.  $2515\text{ cm}^{-1}$  (calcite and dolomite),  $730\text{ cm}^{-1}$  (dolomite) &  $713\text{ cm}^{-1}$  (calcite)] obtained from midDRIFTS spectra were related to carbonate contents separately. Calibration model was also developed via independent calibration (IC) approach taking the whole midDRIFTS spectra. A total number of 126 soil samples (0–30 cm) across two contrasting agroecological regions [Kraichgau (K) and Swabian Alb (SA)], Germany were analysed for their carbonate using Scheibler's method and also scanned by midDRIFTS. The study resulted in a calibration model for carbonate prediction with high accuracy representing  $R^2=0.99$ . In terms of IPA approach, regression analysis between  $PA_{713\text{ cm}^{-1}}$  and carbonate contents showed significant correlation with  $R^2$  value of 0.98 while there was no significant correlation for  $PA_{2515\text{ cm}^{-1}}$  and  $PA_{730\text{ cm}^{-1}}$ . It was attributed to the error made by presence of dolomite in a few samples which is usually ignored during carbonate measurement by Scheibler's method. To conclude, midDRIFTS provide a rapid-throughput approach to predict soil carbonate without need of laboratory measurement. Specifically, the IPA approach for carbonate prediction resulted in a predictive equation as accurate as calibration model developed via IC approach. IPA approach is free of calibration and specifically recommended when the limited number of samples obstacle model calibration via IC approach. However for transfer of index, the approach should be tested beyond carbonate data range used in the current study and further investigations are required to differentiate carbonate composition (e.g. calcite and dolomite) to overcome Scheibler's method weakness in measuring dolomite.

**Keywords:** Soil analysis, soil properties

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## The Effects of Soil Compaction on the Growth of Oil Palm (*Elaeis guineensis* Jacq.) Seedlings

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Mechanisation in oil palm plantation can lead to soil compaction along tracks with bulk densities increasing above  $1.7 \text{ g cm}^{-3}$  at some places, which could lead to negative impact on root development and growth of oil palm. A 7-month pot experiment to evaluate the effect of soil compaction on root development and growth of oil palm seedlings was studied in Nigeria. It was laid out in a completely randomised design (CRD) with six replications. Compaction levels were achieved at soil bulk densities of 1.5, 1.7, 1.9 and a control soil C with no compaction. Growth parameters of plant height (PH), frond width (FW), collar girth (CG) frond length (FL), number of fronds (NF) were measured 3, 5 and 7 months after planting (MAP). At 7 MAP, plant root and biomass attributes such as primary root dry weight (PRDW), primary root length (PRL), and shoot dry weight (SDW) were determined. At 3MAP, PH, CG, FL, and NF were significantly higher for the control while treatments of  $1.5 \text{ g cm}^{-3}$  and  $1.7 \text{ g cm}^{-3}$  gave the highest FW. 5MAP, results for control and  $1.5 \text{ g cm}^{-3}$  treatments were significantly higher for PH, FW, CG, than those of 1.7 and  $1.9 \text{ g cm}^{-3}$ . Control had highest value for FL, and at par with  $1.5, 1.7 \text{ g cm}^{-3}$  treatments, but was significantly different from  $1.9 \text{ g cm}^{-3}$ . At 7MAP, control had highest PH, FW, and NF. However, soils with  $1.5 \text{ g cm}^{-3}$  had highest CG, and FL values. For root biomass and length were also highest for the control. Treatments of  $1.5 \text{ g cm}^{-3}$  gave the highest SDW, but were not significantly different from control. Values for all measured parameters were lowest in  $1.9 \text{ g cm}^{-3}$  treatments. It showed that pots under zero compaction were most effective in improving growth of roots and shoots of oil palm seedlings. Results also indicated that bulk densities of 1.7 and  $1.9 \text{ g cm}^{-3}$  had negative effects on oil palm seedling growth.

**Keywords:** Growth, oil palm, seedling, soil compaction



# Soil (bio)fertilisation

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## **Fertiliser Recommendation Guidelines Based on Soil Tests: Solutions to Farmer Problems or a Tower of Babel?**

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Soil testing has been promoted for many years as the basis for making sound lime and fertiliser use decisions. However misunderstandings still exists on what can and cannot be gained from soil testing. A testament to these misunderstandings is the number of small holder farmers especially in developing countries who do not have access to good historical soil test information. With increasing fertiliser prices, the importance of soil testing for accurate and cost effective fertiliser recommendations has become more important than ever. Thus it is imperative that conclusions drawn based on soil test regardless of which methods are used for the analysis should reflect as much as possible the accurate nutrient requirement for improving crop production if farmers have to benefit. This paper reports on varying recommendations made on same soil samples by six different laboratories in Western Kenya. Twenty soil samples collected from five counties in Kenya were sent to six different laboratories for analysis and providing recommendations on appropriate fertiliser use for each sample based on the soil test results. The different laboratories used different methods of analysis including wet chemistry and near infrared spectroscopy. Variations attributed to the methods of analysis was not the main focus in this study but rather the interpretations derived from the results as the basis of formulating fertiliser recommendation guides. There were highly significant differences on the type and rates of fertiliser and lime recommendations emanating from the six laboratories for the same soil samples. Cost benefit analyses assuming a double maize grain yield increase reveal huge losses farmers would incur up to the tune of 100 USD per hectare while following recommendations from the different laboratories on the same farm. It is clear from this study that the way different government and commercial laboratories interpret how much fertiliser or lime to apply for a given soil test level may still be debatable. This inevitably may lead not only to farmer confusion and mistrust on the recommendations made for fertiliser use based on soil tests but to unwarranted financial loss while at the same time posing serious environmental challenges if not controlled.

**Keywords:** Fertiliser, interpretation, laboratories, recommendation, soil, testing

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## Nutrients from Organic Waste to Improve Soil Health and Enhance Food Security in Sri Lanka

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Effective management of organic waste and wastewater is crucial for preventing environmental pollution and health degradation in Sri Lanka. Since externality costs of open dumping of organic waste and investment costs of sanitary landfilling are quite high, recovering nutrients from biodegradable waste can be an option to reduce the environmental externalities while providing marketable output – compost. Thus, compost from organic waste can also considerably substitute the imports and agricultural applications of chemical fertilisers. Considering these multiple benefits, an economic optimisation model is applied to assess the costs and potentials of compost production and distribution in Sri Lanka. Model was calibrated using data from multiple statistical reports from national and international development organisations. Three scenarios are tested and compared each other. The first scenario considers the situation no organic waste is produced and distributed. The second scenario addresses the case where compost plants are implemented in urban area and produced compost is used in the province where it is produces. The last scenario takes into account possibility of the distribution of the produced compost. The results indicate that recycling organic waste into compost can considerably reduce fertiliser import costs (US\$ 104–145 Million), sanitary landfilling costs (US\$ 214–406 Million) and environmental pollution costs (US\$ 127–142 Million). Inter-provincial distribution of the recovered nutrients from organic waste in Sri Lanka would considerably contribute to reducing the shortage of fertilisers in major farming areas in the country and further reduce the costs of importing chemical fertilisers. Compost quality certification and easiness of obtaining land use rights for establishing compost plants are also important for expansion of nutrients recovery from organic waste streams.

**Keywords:** Compost, environmental externality, fertiliser demand and trade, optimisation model, resources recovery and reuse (RRR)

## Site-Specific Nutrient Requirement for two Different Maize Maturity Groups in Northern Nigerian Savannah Agro-Ecological Zone

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Maize is the most widely grown cereal in Nigeria and yet its productivity has remained low. Blanket and imbalanced nutrient recommendations are one of the major reasons for low nutrient use efficiency and low crop productivity. The QUEFTS (quantitative evaluation of fertility of tropical soils) model was used to estimate site-specific nitrogen (N), phosphorus (P) and potassium (K) requirements for two different maize varieties from two maturity groups, i.e. a hybrid variety *Oba Super-1* (105-110 days to maturity) and an open-pollinated variety *EVDT-W-STR* (90-95 days to maturity) in the northern Nigerian savannah agro-ecological zone. Data from on-farm nutrient omission trials conducted in the 2015 and 2016 rainy seasons across the northern Nigerian savannah were used to calibrate QUEFTS model. The parameters of maximum accumulation (a) and dilution (d) in kg grain per kg nutrient for the model were N (28, 68), P (164, 492), K (20, 211) for *Oba Super-1* and N (32, 71), P (209, 528), K (30, 92) for *EVDT-W-STR*, respectively. The model showed nutrient contents of at 80% yield potential (8000 kg per hectare) of 22.37, 3.39 and 37.95 kg N, P, and K per 1000 kg of *Oba Super-1* grain and 16.94, 3.95 and 29.26 kg N, P and K per 1000 kg of *EVDT-W-STR* grain. These results suggested an average NPK ratio in the plant dry matter of about 6.6:1:11.19 for *Oba Super-1* and 4.3:1:7.4 for *EVDT-W-STR*. The observed grain yields were in good agreement with the values simulated by the calibrated model ( $r^2 = 0.79$  and  $0.91$  for *Oba Super-1* and *EVDT-W-STR*, respectively), indicating that the model can be used for site-specific fertiliser recommendations for maize in the northern Nigerian savannah agro-ecological zone.

**Keywords:** Maize, nutrient requirement, QUEFTS model

## Arbuscular Mycorrhizal Fungi Increase the Abundance of Ammonia-Oxidising Bacteria, but Suppress N<sub>2</sub>O Emissions after Fertilisation

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The potential of the symbiosis between plants and arbuscular mycorrhizal fungi (AMF) to reduce greenhouse gas emissions from soil is gaining scientific attention in the last years. Given the relatively high nitrogen (N) requirements of the AMF and their generally positive effect on host plant growth, AMF may reduce the availability of mineral N that would otherwise be subject to nitrification, which is associated with N<sub>2</sub>O emissions. We investigated the impact of AMF on the growth of tropical grass *Brachiaria decumbens* Stapf. and N<sub>2</sub>O released after urea application. To detect the role of nitrification in N<sub>2</sub>O emissions we used the nitrification inhibitor dicyandiamide (DCD). A mesocosm study (106 days) with two AMF treatments (with and without AMF) and three fertilisation treatments (control, urea and urea+DCD) was set up and plant growth, soil properties and N<sub>2</sub>O emissions were measured for two weeks after fertiliser application. Without DCD, the production of N<sub>2</sub>O was significantly increased by urea, suggesting that inhibition of nitrification can mitigate N<sub>2</sub>O emissions. The cumulative emissions of N<sub>2</sub>O after urea application were reduced by 46 % in the presence of AMF when compared to non-AMF pots. Nevertheless, the abundance of ammonia-oxidising bacteria (AOB) was increased by urea and AMF, while plant growth was reduced by the AMF presence. The increased root:shoot ratio of the biomass in AMF- pots suggests competition for N between AMF and plants. In this study, we demonstrated that immobilisation of N by AMF may significantly reduce N<sub>2</sub>O emissions, at least in the short-term, even when plant growth is reduced. Furthermore, the inverse relationship found between (higher) AOB abundance and (lower) nitrification rates suggests that changes in the activity of AOB, rather than abundance, may be indicative of the impact of the mycorrhizal symbiosis on N cycling in tropical grasslands. Alternatively, the difference between N<sub>2</sub>O emissions from AMF and non-AMF pots may (partly) be explained by increased reduction of N<sub>2</sub>O in the presence of AMF. Longer-term studies are needed to verify whether the observed effects of AMF on N<sub>2</sub>O emissions and/or plant growth persist or are limited to initial immobilisation of N by AMF in N-limited systems.

**Keywords:** Arbuscular mycorrhizal fungi, *Brachiaria*, N<sub>2</sub>O emissions, nitrification, urea

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## Geographical Determinants of the Fertiliser Black Market in North Ethiopia

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As a response to low agricultural productivity, inorganic fertiliser sales have exponentially grown in Ethiopia, and evidence exists of a supply that is beyond the demand in the drier northern parts of the country. Hence, we have investigated the geographical determinants of the fertiliser black market in north Ethiopia. Quantitative data on fertiliser provision and prices on the black market in 2016 were obtained from official statistics and from key informants in each of the 35 studied districts and in all municipalities of the Raya area. Environmental variables were collected from spatial databases. To promote inorganic fertiliser, agricultural experts use incentives, and also barter the purchase of fertiliser by a farmer against food aid or other advantages from the authorities. The high application rate that is aimed at (200 kg ha<sup>-1</sup>) contrasts with the dominance of less-responsive soils in the study area, for which inorganic fertiliser application does not result in higher crop yields, or even leads to root burn. The quantitative analysis shows that 40.7 103 Mg of fertiliser were officially sold in the study area in 2016, which corresponds to 52 kg ha<sup>-1</sup>. This is notably different from the application rate, as reselling widely occurs, at 50 % of the official price for diammonium phosphate (DAP) and 54 % for urea, mostly to users outside the community. By accepting the opportunity offered by agricultural companies and traders, smallholders save themselves from greater losses. The black market rate is strongly and positively correlated to monthly rainfall at sowing time (July 2016) ( $R^2 = 0.44$ ;  $n = 31$ ;  $p < 0.01$ ). In four districts with spate irrigation, black market prices for inorganic fertiliser are extremely low (35 % of the official rate) and small quantities are sold officially (32 kg ha<sup>-1</sup>). This corresponds to the farmers' saying that there "nobody needs inorganic fertiliser since the spate irrigation adds organic and inorganic nutrients yearly". We found similarities to the 'Green Revolution' of the 1970s in Mexico: the forced delivery of high-cost fertiliser, and the reselling at half price in the black market. Inorganic fertilisers are one of the elements that have allowed boosting agricultural production in Ethiopia; our findings indicate however that in the study area, the fertiliser policy needs to be much fine-tuned so that it is led by agronomic needs, rather than by statistics of inorganic fertiliser consumption, that hide complex environmental variability and socio-political relations.

**Keywords:** Black market, chemical fertiliser, integrated soil fertility management, spate irrigation

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## Effect of Application of Composted Manures on Growth, Yield and Yield Components of Sorghum (*Sorghum bicolor* L.) in Sandy Desert Soil, North Kordofan State, Sudan

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Sandy soils contribute significantly in production of important stable food crops. However, the agricultural utilisation of such soils is based on improvement hypothesis of their constraints using organic manures. A two year field experiment was carried out at the Experimental Research Farm of the University of Kordofan (Sudan) to investigate the effects of composted manures and inorganic fertilisers on growth, yield, and yield components of two sorghum varieties (Butana and Arfa Gadmak) cultivated on a sandy soil. Treatments were (1) Control (without fertiliser application), (2) composted farm yard manure (FYM) applied at 20 t ha<sup>-1</sup>, (3) NPK (applied at the rate of 36 kg ha<sup>-1</sup>), combined with composted FYM at 20 t ha<sup>-1</sup>, (4) composted chicken manure (CM) applied at 5 t ha<sup>-1</sup>, (5) NPK (36 kg ha<sup>-1</sup>) combined with composted CM at 5 t ha<sup>-1</sup>, (6) NPK only (36 kg ha<sup>-1</sup>), (7) composted (FYM) combined with composted CM applied each at 12.5 t ha<sup>-1</sup> and (8) NPK (36 kg ha<sup>-1</sup>) combined with composted mixed FYM and CM (applied each at 12.5 t ha<sup>-1</sup>). Treatments were arranged in a split-plot design where varieties were designated to the main plots and fertilisers to the sub plots. Addition of composted manures significantly increased soil organic carbon (OC) by 50 % and available P between 43 to 105 %, whereas, pH and bulk density decreased by 2 % and 6 %, respectively. Integration of organic and inorganic fertilisers increased leaf area index (LAI) over the inorganic source only by 28%, whereas the highest LAI was recorded for sole application of CM (0.82) or CM supplemented with inorganic fertiliser (1.1) as compared to the NPK treatment (0.54). This study also showed differences between varieties. The Butana variety showed a much better nutrients use efficiency as the Arfa Gadmak variety. Incorporation of CM produced a significant higher head seed weight (8.49 g) than that obtained for the combined application of CM and NPK (7.92 g) or for the NPK only treatment (7.99 g). The overall grain yield showed the same pattern: CM > CM integrated with NPK > NPK. However, due to possible N immobilisation, sole application of FYM is not recommended since it decreased grain yield. Consequently, augmenting stable manure with inorganic N resource is recommended for improving sorghum performance. Based on the findings of the N mineralisation carried out in this study, it is recommended that compost application should be done 4 weeks before sowing.

**Keywords:** Compost, dryland, reclamation, soil fertility, yield

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## Response of a Traditional Sweetpotato (*Ipomoea batatas* [L]) Variety to Fertilisation in Leyte, Philippines

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In the Philippines, very few agronomic studies have been done on traditional sweetpotato varieties despite the fact that these are very popular by local consumers. This study evaluated the response of a traditional variety (var. Siete Flores) to NPK fertilisation. Three separate N, P and K fertilisation experiments were laid out arranged in RCBD with 3 replications. The N experiment had 7 levels: 0 (no N), 40, 80, 120, 160, 200, 240 kg ha<sup>-1</sup> N while there were 6 levels for the P experiment: 0 (no P), 20, 40, 60, 80, 120 kg ha<sup>-1</sup> P<sub>2</sub>O<sub>5</sub> and 9 levels for the K experiment: 0 (no K), 30, 60, 90, 120, 160, 200, 240, 280 kg ha<sup>-1</sup> K<sub>2</sub>O. Results revealed that application of different rates of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O significantly increased the dry matter yield, weight of marketable and non-marketable roots, and total root yield. Regardless of fertilisation, the traditional variety had low harvest index of < 20 % (0.20) indicating its low yielding characteristic. The study found that 30 % of the maximum yield of the crop was supplied by the inherent soil N, 50 % by the inherent soil P and 60 % by the inherent soil K. It proved that inherent soil fertility considerably affects the yield of sweetpotato thus, use of blanket fertiliser recommendations as is currently practised in the Philippines, could result in either under or over fertilisation. Optimum rates of NPK application for the soil used were 118, 38 and 90 kg ha<sup>-1</sup> of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O. NPK fertilisation did not significantly influence the nutritional quality of sweetpotato (crude protein, total carbohydrates and crude fibre). Average crude fibre was 20 % indicating that this variety can be promoted as a health food.

**Keywords:** Fertilisation, Philippines, sweetpotato, traditional variety, tropical rootcrops

## Use of *Panicum maximum* as a Source of Biofertiliser and Biochar on Crop Response of *Raphanus sativus* L. in Organic Cultivation

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*Panicum maximum* is an alien invasive perennial weed becoming a threat to environment and agriculture in Sri Lanka. Its control is extremely difficult and expensive due to its heavy dispersion ability. Plant growth promoting rhizobacteria (PGPR) associated with *Panicum maximum* root system are having the ability to produce various phytohormones that improve root growth, adsorption of water and minerals that eventually support successful plant growth. Biochar is a soil amendment that enhances the nutrient retention capacity and reduces the total fertiliser requirements by reducing the loss of nutrients via leaching and high cation & anion exchange capacity. Above ground parts of the *P. maximum* can be used to produce biochar. This research was conducted to evaluate the possibility of using PGPR associated with *P. maximum* roots as a simple and low cost biofertiliser preparation and use of biochar made from *P. maximum* as a soil amendment that could be helpful in controlling *P. maximum* as well as organic agriculture promotion in Sri Lanka. Pieces of *P. maximum* roots and roots washed solution were two forms of biofertilisers. Vegetative growth, yield and quality of the crop *Raphanus sativus* L. (Radish) grown in an organic system was evaluated by applying two forms of biofertilisers and biochar into the soil. Six treatment combinations of biochar and biofertiliser were tested as a pot trial in a polytunnel. A significant highest number of leaves and highest yield parameters were observed in radish grown with root pieces of *Panicum maximum* without biochar. Further it exhibited significantly better sensory properties for radish quality compared to other treatments. It was concluded that root pieces of *P. maximum* can be used as the source of biofertiliser to enhance vegetative growth, yield and quality of radish in organic agriculture. Significant short term effects were not apparent with *P. maximum* biochar application.

**Keywords:** Bio-fertiliser, biochar, *Panicum maximum*, PGPR, radish, roots

## Exploring Input Options for Crop Intensification and Diversification in Maize-Based Farming Systems in Malawi

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Crop production by smallholder farmers in Southern Africa is characterised by cultivation of maize as a staple food on a large share of the agricultural land. Limited nutrient input results in soil nutrient depletion over time. There is need for productive farming systems that are better adapted to a changing climate, and that produce more diverse food to achieve both food and nutrition security. We combined yield results of 50 maize, 28 soybean, 24 groundnut and 26 sweetpotato on-farm input trials with economic analysis and focus group discussions in Central Malawi to explore options for crop intensification and diversification. Due to proper crop management and the use of good varieties in a season with above-average rainfall, excellent mean trial yields of 5.0 t ha<sup>-1</sup> for maize, 3.4 t ha<sup>-1</sup> for soybean, 2.5 t ha<sup>-1</sup> for groundnuts and 13.2 t ha<sup>-1</sup> for sweetpotato were achieved. Responses to various combinations of inorganic fertiliser and lime were highly variable, but applications enhanced yields in all crops. Although maize production and investments in maize fertiliser were not as profitable as the other crops, fertiliser application to maize gave the best returns of food per amount of money invested. Better yield responses and value cost ratios showed that investments in fertiliser and lime in soybean was more worthwhile than in groundnut, though the financial benefits were somewhat hidden by high groundnut prices. While there is potential to derive better financial returns from diversification and intensification with legumes and sweetpotato, farmers prioritise maize in terms of land area and resource allocation. Policies to enhance crop diversification and intensification should address the main constraints of lack of awareness of the agronomic and financial benefits of nutrient application to legumes and sweetpotato, unstable markets, access to credit and access to improved seed.

**Keywords:** Crop diversification, fertiliser, soil fertility, sustainable intensification, yield variability

## Canola Response to Zinc, Sulfur and Boron Fertilisation

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In order to evaluate the effect of boron (B), zinc (Zn) and sulfur (S) application on quantitative and qualitative agronomic characteristics of rapeseed (*Brassica napus* L. var. Hayola 401) in Rasht region, a field experiment was conducted at Rice Research Institute of Iran (Rasht) in a complete randomised block design with 8 treatments and 3 replications. Treatment consisted of control, B, Zn, S, B + Zn, B + S, Zn + S and B + Zn + S. Sulfur was added at the rate of 100 kg ha<sup>-1</sup> before sowing, boron was added as Borax (Na<sub>2</sub>B<sub>4</sub>O<sub>7</sub> · 10H<sub>2</sub>O) at the rate of 1.5 kg ha<sup>-1</sup>, zinc was added as Zn 15 % EDTA at the rate of 1.5 kg ha<sup>-1</sup> were applied to the soil. Results showed that there were significant differences among treatments on traits, seed yield, oil yield, protein content, siliques number at plant, seed number at silique, thousand-seed weight, B, Zn and S contents of seed, oleic, linoleic, linolenic, palmitic, stearic, erusic fatty acids content of rapeseed oil. Highest seed yield (4157.6 kg ha<sup>-1</sup>), oil yield (1770.2 kg ha<sup>-1</sup>), siliques number at plant (195.92 number), seed number at silique (34.31 number) and thousand- seed weigh (3.7 gr) were obtained with B + Zn + S treatments. Maximum protein content in seed of rapeseed (24.62 %) was observed with Zn treatment. Maximum seed B, Zn and S concentrations were recorded in B+ Zn + S treatment which was 15.7, 26.38 and 577.42 mg g<sup>-1</sup>, respectively. Highest percentage oleic (234.8 mg g<sup>-1</sup>) and linolenic (26.98 mg g<sup>-1</sup>) acid in oil seed were obtained from B + Zn + S treatments. Among the different treatments the highest linoleic acid (55.98 mg g<sup>-1</sup>) in oil was recorded in B + Zn treatment. Maximum stearic and erusic acid were obtained from control treatment which was 6.5 mg g<sup>-1</sup> and 1.01mg g<sup>-1</sup> respectively. S + Zn treatment produced the highest palmitic acid (15.53mg g<sup>-1</sup>). This study showed that application of B, Zn and S fertilisers increased quantitative and qualitative yield of canola and improved the fatty acids composition of the oil.

**Keywords:** Element uptake, fatty acid, microelement, oleic acid, protein seed

## **Adoption of Local Organic Resources for Soil Fertility Improvement in Crop Production: Ghana**

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The Organic Resource Management for the improvement of Soil Fertility project (ORM4SOIL: [www.orm4soil.net](http://www.orm4soil.net)) funded by SDC and SNFS as part of the Swiss Program for Research on Global Issues for Development (r4d programme) at the University of Ghana aims at improving soil fertility with concentration on adoption of local organic resources and cost-effective ways of improving soil fertility. This study sought to determine factors that influence intensity of adoption of local organic resources for soil fertility improvement in Ada West District of Ghana. Preliminary data were analysed using descriptive statistics, Tobit model, partial budget and break-even analysis and showed that about 88.7 % of crop farmers use organic materials out of which 49.5 % use animal dropping other than cow dung and 39.2% use matured cow dung only as their local organic resource. Looking at the two-main local organic resources, the intensity (scale of 0-1) of use of other animal manure is 0.43 and the intensity of use of matured cow dung is 0.65. The factors that influence intensity of adoption of matured cow dung or animal manure are their cost, access to credit by farmers, educational level of farmers, farmers membership of farmer based organisations and farmers ownership of their lands.

The partial budget shows that, crop farmers who produced pepper recorded a net loss when they initially replaced inorganic fertiliser with matured cow dung. The break-even point for pepper farmers using matured cow dung in soil fertility improvement is approximately 48 kg of pepper at a selling price of GHS 1200. The most pressing constraint of crop farmers in the use of matured cow dung and other animal manure for soil fertility improvement is its labour intensiveness. It is recommended that extension agents concentrate on training farmers on how to combine the use of matured cow dung and other animal manure with inorganic fertiliser in the right quantity to maximize production. Both cattle farmers and crop farmers should be given technical training in compost preparation to reduce the bulkiness and labour intensiveness of dealing with cow dung and other animal manure in soil fertility improvement.

**Keywords:** Adoption, crop farmers, Ghana, local organic resources, soil fertility improvement

## Diversity of Nitrogen-Fixing Bacteria Associated with Yams (*Dioscorea* spp.)

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Yams are important tuber crops in the tropical zones. Nitrogen is one of the limiting nutrients in yam production. In Africa, where the highest production is held, yam tuber yields are very low due to loss of soil fertility, and to unaffordable and expansive mineral fertilisers which are also not eco-friendly. In this context, identifying yam accessions that can rely on biological nitrogen fixation is necessary for achieving efficient and sustainable yam production. The aim of this study was to isolate and identify endophytic diazotrophic bacteria of yam. Endophytic bacteria were isolated from surface-sterilized roots, stems and leaves of yam accessions grown in nutrient-poor subsoil 160 days after planting. The nitrogen-free MR medium was used for culturing and purifying the endophytic bacteria. Sequencing of the 16S rRNA genes was performed for the fast-growing pure colonies. In total, 41 endophytes were found, belonging to 18 bacterial genera including *Bacillus*, *Rhizobium*, *Burkholderia*, *Curtobacterium*, *Devosia*, *Mesorhizobium*, *Paenibacillus*, *Sphingomonas*, *Achromobacter*, *Bradyrhizobium*, *Ensifer*, *Enterobacter*, *Kocuria*, *Mycobacterium*, *Neorhizobium*, *Pseudaminobacter* and *Pseudoxanthomonas*. Strains of Proteobacteria accounted for 56.10 % of total isolates, followed by Firmicutes (34.15 %) and Actinobacteria (9.75 %). Most endophytes were isolated from stems (21) and roots (14), while only six were from the leaves. This is, to our knowledge, the first report where bacterial strains related to *Curtobacterium* sp., *Ensifer* sp., *Kocuria* sp., *Mesorhizobium camelthorni*, *Mycobacterium cosmeticum*, *Pseudoxanthomonas indica*, *Paenibacillus panacisoli* and *Neorhizobium huautlense* were fast grown on nitrogen-free medium, and their nitrogenase activities assessed through acetylene reduction assay. In *D. esculenta*, the highest nitrogenase activity ( $57.4 \text{ nmol C}_2\text{H}_4 \text{ tube}^{-1} \text{ day}^{-1}$ ) was recorded in the isolate E1T0R\_Y6, belonging to the genus *Bradyrhizobium* sp., while it was  $164 \text{ nmol C}_2\text{H}_4 \text{ tube}^{-1} \text{ day}^{-1}$  in *D. alata*, strain A23T1R\_Y40, a strain related to the bacterial genus *Ensifer* sp. The plant growth promotion activities (PGP) of these isolates are to be investigated for selecting most promising nitrogen-fixing bacteria of yams.

Accession numbers of the bacterial 16S rRNA sequences obtained in this were submitted to the DNA Data Bank of Japan (DDBJ).

**Keywords:** Diazotrophes, *Dioscorea*, endophytes, yams

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## Impact of Alternative Management Practice on Fertiliser Recovery by Cotton in Different Soil Types of West-Africa

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Cotton is still one of the most dominating cash crops grown by the smallholder famers in most of the countries of West-Africa. However, it is mainly grown in the lands with inheritably poor soil fertility and therefore, the most limiting nutrient, nitrogen, is often applied in a greater quantity. As a consequence, the task of improving nitrogen use efficiency by cotton cultivated in such soils has become a major challenge. In an attempt to recommend an alternative management practice for improving crop nutrient uptake, use efficiency, and yield, an experiment was conducted in 2013 on a Haplic Lixisol and a Plinthic Lixisol in Ouriyouri, Benin Republic, and on a Ferric Lixisol and an Eutric Plinthosol in Tambiri, Burkina-Faso. The main goal of this study was to assess the single and interactive effects of tillage, crop residue incorporation, and nitrogen management on cotton nitrogen uptake (NU), and apparent nutrient recovery efficiency (ANR) from N fertiliser under 4 different soil types. The experiment was a strip-split-plot design with four replicates comprising two tillage systems (contour ridge and reduced tillage) in main plots, and two levels of crop residue (with and without) and three mineral nitrogen fertiliser rates (0, 45, 90 kg ha<sup>-1</sup>) randomised within the sub-plots. At 4 weeks (vegetative stage) and 8 weeks (reproductive stage) after planting, whole cotton plants were sampled and analysed for nitrogen content. In Ferric Lixisol, Eutric Plinthosol, and Haplic Lixisol, the highest level of both NU and ANR was recorded under contour tillage with crop residue incorporation and 90 kg ha<sup>-1</sup> N dose. On the other hand, in Plinthic Lixisol, NU and ANR was highest under contour ridge tillage with crop residue and 45 kg ha<sup>-1</sup> N dose. A higher NU and ANR by contour ridge tillage, crop residue incorporation and judicious N application also significantly increased cotton yield at all the soil types. Therefore, the use of contour ridge tillage with judicious application of nitrogen fertiliser and crop residue should be promoted for the smallholder cotton farmers in West Africa as a measure to optimise farming practices.

**Keywords:** alternative management practice, apparent nutrient recovery efficiency, cotton, nitrogen uptake, soil type, West-Africa



## Effect of Nitrogen Stabilizing and Potassium and Phosphorus Solubilising Bacteria on Mungbean (*Vigna radiata*) Yield

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Biological fertilisers as an alternative to chemical fertilisers in sustainable agriculture can improve the quantitative and qualitative yield of crops. In order to investigate the effect of nitrogen stabilising bacteria, solubilising bacteria of potassium and phosphorus on mung bean yield, a field experiment was carried out using a randomised complete block with factorial treatment structure. Two mungbean (*Vigna radiata*) cultivars (Dezfouli & hendi) were cultivated in six treatments and three replications at the Agricultural Research Station, Ferdowsi University of Mashhad, Iran in 2017. The biofertiliser treatments used in this study included: 1) nitro power bacter (NPB) 2) phosphate power bacter (PhPB) 3) potassium power bacter (PPB) 4) nitro power bacter+ phosphate power bacter + potassium power 5) nitrogen fertiliser (N) 6) control (C) without any fertiliser. The results indicated that application of investigated bacteria had significant effect on mungbean yield ( $p < 0.05$ ). The highest biomass and grain yield was obtained for Dezfouli cultivar in NPB + PhPB + PPB bacteria-integrated treatment with an average of 6555 and 1558 kg ha<sup>-1</sup>. The lowest amount was observed for Hendi cultivar in control treatment with an average of 3518 and 1393 kg ha<sup>-1</sup>. The effect of treatments on yield components also was significant ( $p < 0.05$ ). As a result, the highest number of pods per plant and number of seeds per pod were obtained in the NPB+PhPB+PPB treatment as well. These two parameters had the largest role in yield improvement especially in bacterial-induced treatments. The superior treatment in this experiment was attributed to the interaction of biofertiliser nitrogen, phosphorus and potassium, which caused the highest yield and yield components in mungbean plants. Results of the present study revealed that the mixed application of nitrogen stabilising bacteria, solubilising bacteria of potassium and phosphorus as biological can not only improve yield of mungbean but also can reduce chemical inputs in crop production systems.

**Keywords:** Biofertiliser, mung bean, sustainable agriculture, yield components

## Combined Tied Ridge, Fertiliser Microdosing and Biochar Effects on Maize Production under Contrasting Water Supply

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In many developing countries staple food production is limited due to soils with low agricultural potential, constraints in terms of fertiliser accessibility and low and/or erratic rainfall. There are well-known agricultural practices to meet those challenges: *In-situ* rain-water harvesting with tied ridges, fertiliser microdosing and biochar application to soil. However, their combinations have rarely been studied under varying irrigation frequencies.

We conducted a field trial in split-plot design on soil with low natural fertility in Tanzania over two seasons with contrasting water supply in 2016 and 2017. Tied ridges, chemical fertiliser microdosing (25 %) and maize cob biochar were applied and their effects on maize grain yield, biomass, plant height, leaf area index, and soil moisture content were investigated.

The slightly alkaline biochar provided P and K to the soil. Under low irrigation frequency, tied ridges conserved soil moisture and tended to increase yield. Fertiliser microdosing increased yield under both irrigation frequencies compared to the control. Biochar alone increased grain yield only at high rates of 10 t ha<sup>-1</sup> and only under low-frequency irrigation. However, in combination with fertiliser microdosing, biochar application had greater impact on yield: Even at lower application rates of 5 t ha<sup>-1</sup>, biochar combined with fertiliser microdosing increased yields under flat tillage and under both irrigation frequencies compared to the control.

Thus, for higher yields, fertiliser microdosing combined with biochar can be recommended under either precipitation frequency. Furthermore, the crop position on the tied ridge needs to be considered carefully depending on the water supply situation to optimise water management.

**Keywords:** Biochar, fertiliser microdosing, maize, rainwater harvesting, tied ridge

## Varietal Differences in Tuber Yield and Fertiliser Response in a F1 Mapping Population of Water Yam (*Dioscorea alata* L.)

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Yam (*Dioscorea* spp.) is important for food security in West Africa which produces more than 90 % of the worldwide production. Development of high-yielding varieties and varieties with abiotic stress tolerance (low soil fertility) is strongly required, and also it is one of the most important targets of the yam breeding strategy in West Africa. Although soil fertiliser management is one of the most interesting topics on the strategy, results on yam production is differently estimated. In this study, we aimed at clarifying the varietal differences in tuber yield and fertiliser response, and to select varieties with low soil fertility tolerance within a segregating *D. alata* F1 population. Ninety-four clones derived from crosses between TDa 00/00194 (female, late maturity) and TDa 02/00012 (male, early maturity) were grown under field conditions at Ibadan, Nigeria. A field study evaluated the varietal difference in tuber yield and growth period of water yam when grown with (90 kg N ha<sup>-1</sup>, 75 kg K ha<sup>-1</sup>, 50 kg P ha<sup>-1</sup>) or without fertiliser in a field with low soil fertility condition. Growth period was calculated from sprouting date to senescence of the aerial part of each plant. The number of tubers and fresh tuber weight of each tuber produced by each plant were recorded on 15 January, 2018. A wide range of growth period and yield differences among the clones was observed within the F1 mapping population. It was possible to identify genotypes showing high yield even under low fertility soil condition. A significant interaction effect between fertilisation and variety on tuber yield was observed, and the presence of clones responding to fertiliser application was found within the trial population. Varietal differences in fertilisation response may be a factor that has contributed to variable results in previous studies. In future experiments, we plan to clarify the physiological characteristics of fertiliser use efficiency and nutrient absorption in water yam.

**Keywords:** Fertiliser response, low soil fertility condition, varietal difference, water yam

## Linking Leaf Color Charts and Crop N-Status to Guide Fertiliser Application in Highland Rice Production Systems of Rwanda

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In farmers' fields or on experimental field stations sophisticated measurements for monitoring crop nutrient status are often not available. However, the nutrient status of the rice crop is an important indicator to guide fertiliser application strategies for nitrogen (N). Farmers aim to improve fertiliser applications with regards to crop, planting date, and region rather than following blanket N recommendations. The International Rice Research Institute has developed a Leaf Color Chart (LCC) as a diagnostic tool based on the greenness value of leaves to help farmers decide when to apply fertiliser. This method does not take into account differences in leaf greenness that are due to variety, plant type, or leaf thickness. The aim of this work was to determine the influence of leaf thickness on the accuracy and transferability of LCC values with regards to actual, genotypic N status.

The study was conducted at two sites differing in altitude along a temperature gradient in Rwanda from May-November 2017. Two contrasting rice varieties were used. Each variety was subjected to two nitrogen application rates (80 kg ha<sup>-1</sup>, 160 kg ha<sup>-1</sup>). A Minolta SPAD-Meter was used to evaluate the crops current N status using the youngest fully developed leaf on the main tiller. SPAD and LCC values were recorded one day prior to fertiliser applications, and up to five consecutive days after fertiliser applications at mid tillering, panicle initiation, and heading stage. Following published procedures, SPAD values were corrected for leaf thickness. This way, SPAD values represented the N-status of the plant and were used to calibrate LCC to actual crop N status. Results show crop N status differed significantly between altitudes, varieties, and N application rates. Results will be analysed in terms of method applicability and phenology and will be discussed on the poster.

**Keywords:** Crop N-status, ICC, rice, SPAD

## Improving Sweetpotato Production through Sweetpotato - Legume Intercropping and Use of Phosphorus Fertilisers in Mozambique

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Sweetpotato yields are adversely reduced by drought and this is often exacerbated by poor soil fertility in Mozambique. Many smallholder farmers have no access to irrigation facilities and inorganic fertilisers to improve crop yields. The objectives of the study were to evaluate the effectiveness of sweetpotato-legume intercropping and phosphorus (P) fertilisation on the storage root yield and nutritional qualities of an orange fleshed sweetpotato variety, Namanga. A field experiment was carried out at Umbeluzi Research Station in southern Mozambique. The experiments were carried out during three growing seasons from 2013 to 2015 using a factorial design in a split plot arrangement. Main plot treatments were 7 crop combinations; sole sweetpotato, sole groundnut, sole soybean, sweetpotato-groundnut, sweetpotato-soybean, sweetpotato-groundnut-soybean, groundnut-soybeans intercropping. The subplot treatments were 0, 20 and 40 kg P ha<sup>-1</sup> applied at planting. Sweetpotato storage root and vine yields were agronomic traits measured at maturity using a scale. Nutritional quality traits measured were dry matter content, fructose, glucose, starch, sucrose,  $\beta$ -carotene, iron (Fe) and zinc (Zn). Roots were sliced to get 100 g compound sample, freeze dried for 72 hours, weighed, milled then analysed for nutrition content using near-infrared reflectance spectroscopy. Soil fertility parameters measured were cation exchange capacity (CEC), total nitrogen (N), available N and potassium (K). Phosphorus fertilisation at 40 kg ha<sup>-1</sup> produced highest dry matter content, glucose, starch, sucrose in sweetpotato storage roots, vine yield, soil CEC, total N, available N and K. Phosphorus had no effect on  $\beta$ -carotene, Fe and Zn content in storage roots ( $p > 0.005$ ). Sweetpotato-soybean intercropping at 40 kg P ha<sup>-1</sup> produced highest vine yield, soil nutrients and CEC. Phosphorus at 20 kg ha<sup>-1</sup> produced best storage root yield of 16.3 t ha<sup>-1</sup>. Sweetpotato-groundnut intercropping produced best sweetpotato storage root yield and highest land equivalent ratio of 1.6. Sweetpotato-legume intercropping produced highest Zn and Fe content in sweetpotato storage roots. Sweetpotato-groundnut intercropping at 20 kg P ha<sup>-1</sup> was best for sweetpotato storage root yield. This research recommends sweetpotato-groundnut intercropping at 20 kg P ha<sup>-1</sup> for sweetpotato storage root yield maximisation and sweetpotato-soybean at 40 kg P ha<sup>-1</sup> for best sweetpotato nutritional value.

**Keywords:** Groundnut, intercropping, smallholder farmers, soybean, sweetpotato

## Do Mycorrhiza Play a Role in the BNI Performance of *Brachiaria humidicola*?

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The tropical forage *Brachiaria humidicola* (Bh), a plant with recognised Biological Nitrification Inhibition (BNI) potential, has been acknowledged as a model crop to investigate the BNI phenomenon. BNI is originally thought to be an allelochemical phenomenon, that inhibits the activity of soil nitrifying bacteria and archaea. Our studies on BNI have revealed, however, that also inter-microbial competition for nitrogen might play an important role in BNI. Recent research suggested that besides heterotrophic bacteria and archaea also symbiotic arbuscular mycorrhizal fungi (AMF) in the direct vicinity of the plant roots may contribute to the immobilisation of ammonium ( $\text{NH}_4^+$ ) leading to low nitrification rates in Bh pastures. It must be emphasised that until now no in-depth research on the role of AMF in BNI has been published.

To fill this knowledge gap, the presented research was conducted at the end of a two-factorial pot experiment with the factors soil type (three different soils) and Bh genotypes (three genotypes with different BNI activity). The potential role of AMF for BNI was investigated in topsoil (0–10 cm) and roots collected 14 days after  $\text{NH}_4^+$  fertilisation. Various indicators for the BNI performance (nitrate formation in soil solution, abundance of ammonium oxidising bacteria and archaea (AOB and AOA) and  $\text{N}_2\text{O}$  emissions have been measured before and after the fertilisation event. In the next step, colonisation of AMF on Bh roots was assessed via root staining techniques. Total abundance of mycorrhizal fungi in soil was quantified via qPCR techniques using the AMF specific primer developed by Krüger et al. 2009 and community composition of AMF was assessed by denaturing gradient gel electrophoresis (DGGE) analysis using DNA extracted from the roots. The combination of classical and molecular techniques to study AMF dynamics will allow answering the question to what extent AMF may play a role in the BNI performance of different Bh genotypes.

**Keywords:** Arbuscular mycorrhizal fungi, biological nitrification inhibition, *Brachiaria* grasses, denaturing gradient gel electrophoresis, mycorrhizal symbiosis, qPCR

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## Effect of Liquid Digestate of a Biogas Plant Using Rice Straw, as Biofertiliser in Paddy Rice Cultivation in Comparison with Mineral Fertiliser in Tien Giang Province, Vietnam

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Appropriate fertilisation is very important for sustainable environmental friendly agriculture, in particular in paddy rice cultivation the main agricultural crop in Vietnam. Therefore, mineral fertilisers should be partly replaced with organic fertilisers, e.g. by using of liquid digestate of biogas plants, using mainly rice straw and cow dung. First experiments in containers in 2017 showed there are possibilities to change the traditional fertilisation methods. In the first field experiment from January to April 2018, conducted in the Mekong delta district Cai Be, province Tien Giang, the aim was to verify whether the first results can be confirmed and to test the effect of biofertiliser under typical field conditions with digestate from the same biogas plant. This experiment was designed with three different mineral and organic fertiliser treatments (MF and OF) using different ratio of nitrogen source: (1) 100 % mineral fertiliser (2) 100 % biofertiliser and (3) 50 % mineral fertiliser and 50 % biofertiliser. Following parameters were determined, length of the paddy rice inflorescences, the number of seeds, and the marketable rice grains. The results showed that, the length of the paddy rice inflorescences and the marketable rice grains of treatment 1, 2, 3 were  $22.75 \pm 0.48$  cm;  $24.68 \pm 0.28$  cm;  $21.67 \pm 2.72$  cm and  $92.64 \pm 1.39\%$ ;  $88.55 \pm 4.01\%$ ;  $91.48 \pm 0.82\%$ , respectively. The most important parameter is the yield that means the length of the paddy rice inflorescences and the marketable rice grains. The highest length was determined in the treatment 2 in comparison to other treatments, but their marketable yield was lowest comparison to other treatments. The results also showed that the yield of treatment 3 (MF: OF 50:50) was similar to control treatment (100 % MF). It can be concluded that it is possible to replace mineral fertiliser in rice cultivation to some extent with biofertiliser as for example with digestate from biogas plants. Further experiments regarding the amount of biofertiliser, the frequency of application and their dosage, as well the influences of the microbial activity in the soil are necessary.

**Keywords:** Biofertiliser, biogas, liquid waste biogas systems

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## Effect of PGPR and *Rhizobium phaseoli* on Nitrogen Fixation of Mungbean (*Vigna radiata*) under Dryland Conditions

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Today, food security has to be reached through a sustainability approach, where the farming systems in order to remain productive in the long term have to replenish the nutrients removed from soil. The need to develop sustainable practices and use resources efficiently, highlight the potential role of biological nitrogen fixation (BNF) as a primary N source in agriculture. Mungbean (*Vigna radiata*) has been suggested as a short-duration summer crop to be incorporated into the soil after harvesting the grain/pods. It is a crop well adapted to the dryland conditions of the tropics and subtropics. Due to the lack of summer rains or their erratic distribution, mungbeans are exposed to severe water deficits associated with salt stress, which results in lower grain yields and inefficient BNF. Plant growth promoting rhizobacteria (PGPR) showed the potential to diminish the negative effects caused by drought and salinity stress. This research work aims to identify the effects of three PGPR and their combination on mungbean N fixation under dryland conditions of Pakistan. In a field trial, two mungbean accessions were tested with five inoculation treatments: M9 (*Rhizobium phaseoli*), Mk20 (*Pseudomonas fluorescens*), Y16 (*Bacillus subtilis*), MIX (*R. phaseoli* + *P. fluorescens* + *B. subtilis*) and control (without bacterial inoculum). Plants were harvested at maturity to assess N fixation (%Ndfa), total N content and biomass accumulation. Chlorophyll content and proline content were assessed at flowering stage. MIX and Mk20 obtained the highest %Ndfa, while MIX and Y16 accumulated the highest total dry matter. In contrast, the controls always had the lowest chlorophyll content, total dry matter and %Ndfa. These results indicate that all tested bacterial inoculations increased biomass and chlorophyll content, but particularly their combination enhanced N fixation. Y16 accumulated the highest proline content. This is a response related to drought stress, suggesting that the best inoculation treatment to enhance BNF and yield is a combination of Mk20 and M9 only.

**Keywords:** Drought stress, drylands, nitrogen fixation, PGPR, *Rhizobium phaseoli*, *Vigna radiata*

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## Effect of Fertiliser Rates and Splits on Lowland Rice in two Temperature Environments in Rwanda – With a Special Focus on the Effectivity of Basal Applications

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In Rwanda, rice is cultivated across a large altitude gradient. However, the recommended fertiliser application rate does not differ across these altitude gradients, resulting in a mismatch between nutrient requirements in specific growth stages of the plant and fertiliser application strategies. Hypothetically, in early growth stages rice at high altitudes will take up smaller amounts of nitrogen as compared to lower altitudes as low root zone temperatures may slow down growth and N uptake rates. Therefore, the basal N application could be reduced or omitted thus reducing unproductive losses of applied fertiliser. To test this hypothesis, field trials were established at two locations (900 and 1600 m a.s.l.) in Rwanda, investigating the response of 5 contrasting rice varieties to three N application rates (80, 120 and 160 kg ha<sup>-1</sup>). Different splits of these fertilisers were tested, with and without basal dressing and three further top dressings at mid-tillering, panicle initiation and heading. Two sowings were conducted in 2016 (February and July) and two others in 2017 (January and April). Duration to flowering was 25–34 days, 33–47, 39–46 and 83–123 longer at high altitude than at low altitude during the first, second, third and fourth planting dates, respectively, depending on the genotype due to thermal conditions. Mean air temperatures were 4.91°C, 4.10°C, 4.14°C and 4.96°C lower at high altitude during the first, second, third and fourth planting dates respectively. At the high altitude, when shifting the N application from basal to mid-tillering and panicle initiation, the number of panicles, percentage filled grains, 1000-grain weight and grain yield increased. At the low altitude, there was no significant effect of different N splits tested for yield and yield components. As expected from the temperature conditions, the grain filling percentage was higher at the low altitude as compared to the high altitude. Yields at low altitude were higher than at high altitude across the planting dates. The potential improvements to fertiliser recommendations might include omission of basal N and shifting the N application to mid-tillering and panicle initiation stages at high altitudes.

**Keywords:** Altitude gradient, nitrogen, planting dates

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## Effects of Biochar and the Use of TLUD-Reactors in Rural Areas for Cooking and Soil

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On-farm crop residues are often left unutilised or not efficiently used. Often they are left to be decomposed or, sometimes, in-situ used by livestock. Crop by-products, like maize cobs and residues from primary processing, especially from threshing and shelling, have a high percentage of lignified structural components and therefore are suitable for thermo-chemical conversion. A pyrolysis-treatment of these residues can provide thermal energy for cooking applications as well as for biochar production, which can be used as a soil amendment to improve soil structure and cation exchange capacity as well as to contribute to carbon sequestration. A top-lid-up-draft (TLUD) barrel-reactor was developed at the University of Hohenheim and iteratively adjusted (in the project of Trans-SEC) for the use at grass-root level, which led to a cooking extension of the device. It can be built from scrap material (oil drums) locally available and is capable of sustaining high temperatures of up to 400°C. The drum has a screw-top lid, and a central pipe with a diameter of 10 cm perforated with a dense array of 10 mm holes made throughout its height. Test results from the UPS farmers group in one of the case study villages showed that after pyrolysis for about two hours from 15 kg of maize cobs about 4.4 kg of biochar (29 %) could be produced. In the poster we will discuss the amount of biochar amendment needed to increase soil fertility and crop productivity for certain farming areas and site conditions derived from data of field trials with soybean and grains in China and Germany and different maize cropping systems in Tanzania. According to soil types and water regimes we found different yield responds after biochar application. Recommended rates of 5–10 (up to 20) tons biochar per hectare limit the suitability to small gardens or need to extend the size of the reactor to the scale of a big charcoal kiln.

**Keywords:** Biochar, charcoal, crop residues, energy stacking, energy transition, field trials, pyrolyzer, soil improvement, woodfuel

## Effects of Organic Manure and Crop Rotation Systems on the Grain Yield of Wheat (*Triticum aestivum* L.) in the Highlands of Ethiopia

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Concerns on soil fertility degradation were resonating for decades in wheat growing highlands of Ethiopia. Important physicochemical properties of the soil have been below the critical level to support crop growth. As a result, low crop yields lead to a shortage of food supply, which is the dominant challenge of the region. Thus, an experiment initiated to improve the productivity of wheat through organic treatments and crop rotation systems. Four levels of organic treatments and annually varied crop rotation systems arranged factorially and laid out in a Randomised Complete Block Design (RCBD) with four replications. The organic treatments included V1= 0 t ha<sup>-1</sup> FYM (farmyard manure); V2 = 2.5 t ha<sup>-1</sup> FSB (fresh *Sesbania* biomass); V3=5 t ha<sup>-1</sup> FYM and V4=5 t ha<sup>-1</sup> FYM +2.5 t ha<sup>-1</sup> FSB. In the first year, wheat was planted with different levels of organic treatments with undersowing lupine (R2) and sole wheat (R1). In the second year, wheat was planted with different levels of organic treatments. In the third year, the rotation systems include R3 = potato-clover-wheat; R4 = wheat under sown with lupine-potato under sown with lupine-wheat and R5= lupine-potato undersowing lupine-wheat. Data on plant height, thousand seed weight, and grain yield of wheat recorded and analysed using SAS. Results showed increasing grain yields of wheat over the period of the three years across all treatments. Among all, the highest grain yield of wheat (4.48 t ha<sup>-1</sup>) was recorded at the interaction effect of 5 t ha<sup>-1</sup> FYM +2.5 t ha<sup>-1</sup> FSB and potato-clover-wheat rotation system in the third year and could be recommended as an alternative soil fertility management system to attain optimum yield in the highlands of Ethiopia.

**Keywords:** Cropping pattern, natural fertiliser, productivity, soil fertility

## Confirmation and Functional Characterisation of Potassium Ion Channel Gene for Iron Toxicity Tolerance in Rice

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Iron toxicity is a major nutrient disorder in rice caused by an excessive uptake of iron occurring in flooded soils due to low redox potential, which favours the formation of the soluble and plant available form,  $\text{Fe}^{2+}$  (ferrous). After uptake of  $\text{Fe}^{2+}$  via the rhizodermis, Fe will be translocated into the shoot. In plant cells  $\text{Fe}^{2+}$  catalyzes the formation of reactive oxygen species (ROS) via the Fenton reaction which is known to cause irreversible damage to biomolecules such as lipids, proteins and DNA resulting in a reduced plant growth and yield loss. In our previous study, QTL related to the shoot iron concentration in Fe-toxic conditions were identified with GWAS study. This led to the identification of a candidate gene for Fe-exclusion, i.e. a putative potassium (K) ion channel gene OsAKT1 (LOC\_Os01g45990). We hypothesised that K and Fe might have antagonistic interactions in Fe toxic conditions. In order to proof this concept, experiments were conducted with two knockout mutant lines for the candidate genes named osakt1-1 and osakt1-2. Semi-quantitative RT-PCR confirmed that the target gene was not expressed in mutant lines. Mutants and wild-types were grown for 4 weeks in a hydroponic culture followed by a five day, 1000 ppm of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  treatment to simulate an acute iron stress. The iron treatment led shoot Fe concentrations exceeding toxicity threshold, to visible symptom formation quantified as Leaf Bronzing Score (LBS), and negatively affected spectral reflectance indices such as the normalised difference vegetation index (NDVI) and photochemical reflectance index (PRI), lipid peroxidation, as well as the uptake of potassium. The knock out mutant osakt1-1 had significantly lower shoot K concentration but higher Fe concentration, along with significantly higher LBS, NDVI and PRI compared to the wild-types. Therefore, antagonistic translocation of Fe and K to the leaf sheath and leaf blade could be detected which underpins our hypothesis. Ongoing experiments aim at further elucidating the mechanism behind the antagonistic interaction of Fe and K, and the resulting susceptibility of osakt1 mutants, including the role of antioxidant enzymes (ROS-scavengers). Our results therefore help to explain the important role of K in Fe toxicity tolerance.

**Keywords:** Genotype tolerance, iron toxicity, potassium, rice, tolerance mechanism

# Land degradation and livelihoods for the Sahel

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# Land Degradation Neutrality: Global Vision and Perspectives for Africa

BARRON ORR

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Land Degradation Neutrality (LDN) is the new paradigm for avoiding, reducing and reversing land degradation in an integrated way as a means of attaining the Rio+20 aspiration for a land degradation-neutral world. Defined as “a state whereby the amount and quality of land resources necessary to support ecosystem functions and services and enhance food security remain stable or increase within specified temporal and spatial scales and ecosystems”, the goal of LDN is maintaining or enhancing the land resource base - in other words, the stocks of natural capital associated with land resources and the ecosystem services that flow from them. LDN is also fundamental for pursuing Sustainable Development Goal (SDG) 15 “Life on Land”. The recently published Scientific Conceptual Framework for Land Degradation Neutrality (Orr *et al.* 2017; Cowie *et al.* 2018) provides a scientific foundation for understanding, implementing and monitoring LDN.

The framework is structured around five ‘modules’: Vision of LDN, which captures the goal that LDN is intended to achieve; Frame of Reference, that explains the LDN baseline against which achievement is measured; Mechanism for Neutrality, that describes the counterbalancing mechanism; Achieving Neutrality, that presents the theory of change (logic model) articulating the pathway for implementing LDN, including preparatory analysis and enabling policies; and Monitoring Neutrality, which presents the LDN indicators. Principles are provided to govern application of the framework and to help prevent unintended outcomes during implementation and monitoring of LDN. These principles are designed to encourage the creation of an enabling environment which incentivizes the pursuit of LDN while encouraging responsible governance to help ensure better access, control and stewardship over land, including strengthening tenure security, access and user rights for women and men, in particular the poor and vulnerable. It also incorporates the need for gender-responsive policies and measures designed to ensure the full and effective participation of both men and women in planning, decision-making and implementation at all levels. Coordinating the theoretical development of the framework with regular input from on-the-ground teams who were conducting training events to launch the LDN Target Setting Program (TSP) led real-time testing of scientific concepts under very practical conditions. This has ensured that the conceptual framework is firmly grounded in science with clear entry points for developing the guidance necessary to achieve or exceed LDN into the future.

The conceptual framework has been designed to create a bridge between the vision and the practical implementation of LDN, by defining LDN in operational terms. This practical approach has led to significant country buy-in: to date, 118 countries – including 51 in Africa – have embarked on the process of establishing national targets on LDN.

**Keywords:** Land degradation

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## Restoration Pathways for Degraded Land in West African Sahel and Dry Savannah: A Review

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Developing countries, especially dryland areas in sub-Saharan Africa, depend strongly on ecosystem services generated by natural resources. Today, the rapidly growing population and the competing demands for food, feed, fuel, fibre are leading to degradation of forests and agricultural land. Globally, it is estimated that 10 – 20 % of drylands are already degraded and about 12 million ha are degraded each year. Thus, livelihood is vulnerable in many rural areas and likely to sharpen due to anticipated climate change. Land restoration is therefore an urgent priority if future food security and ecosystem's resilience are to be achieved. Several local, regional and global initiatives have been launched – with more or less success – to combat land degradation. Past efforts have generated some lessons that can be used to guide future initiatives. We conducted a comprehensive review of the existing literature to collate information on the current state-of-knowledge about degraded drylands rehabilitation, identify the ingredients of success and flesh out opportunities for scaling. It was found that restoration pathways ranged from passive (prevention of disturbance agents to enhance vegetation recovery) to active measures (e.g. site-specific biological and physical intervention for soil and water conservation, enrichment planting, sand dune fixation, farmers' managed natural regeneration (FMNR), agroforestry, direct seeding of grass, controlled grazing and prescribed fire). The diversity of land restoration initiatives is an indication of the dynamism of farmers, development agencies and researchers to curb land degradation. Success of restoration can generally be attributed to a combination direct and indirect incentives which have led farmers to adopt, and continue to use the rehabilitation practices. Farmers use different options or their combination depending on agroecological and socio-economic conditions. The cost effectiveness of these options still need to be evaluated to build evidence on what works, for whom, how, and at what cost across heterogeneous contexts.

**Keywords:** Climate change, desertification, ecosystem management, land degradation, socio-ecological systems, West Africa



## Empowering Women Farmers and Providing Nutritional Benefits to Households through Degraded Landscapes Regeneration in Niger

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Degraded lands in a landscape are used mainly for grazing and firewood harvesting. They have low agricultural production potential. Such areas have become degraded through overuse and removal of surface cover and associated erosion processes. The soil surface is crusted following alternate exposure to rain and sun, which causes high runoff and soil erosion, minimises water infiltration and hinders seedling emergence. These soils have high clay content, which offers the advantage of high cation exchange capacity (CEC) and water holding capacity. They have the potential to re-establish agricultural production if the compacted layer is broken and some organic fertiliser added. Farmers in the Sahel countries have developed water harvesting-based technologies (zai pits or half-moons) to bring back into production the degraded lands.

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has developed a gender sensitive system approach named “Bio-reclamation of Degraded Land” or BDL, that combines indigenous or improved water harvesting technologies (planting pits, half-moon and trenches), the application of composted organic residues and plantation of high value fruit trees (*Moringa oleifera*, *Ziziphus mauritiana*) and annual indigenous vegetables like okra (*Abelmoschus esculentus*), roselle (*Hibiscus sabdarifa*) and *Senna obtusifolia*, that are resilient to drought.

Knowing that leafy vegetables harvested during the season are mainly used for household consumption, we have monitored potential individual total gain from the allocated 200 m<sup>2</sup> plot in a BDL site during the 2017 wet season in the districts of Mayahi (Maradi region) and Kantche (Zinder region) in Niger. The data showed contrasting results depending on the level of effort the women participants made to care for the sites. In Mayahi, a maximum gain of 383 \$US could be obtained if they were to market all the production. In Kantche the maximum obtained was 340 \$US. The result also shows a large variability in the production effort of participants. BDL implementation can be seen as a solution to sustainably improve the livelihood and health of poor women farmers through the supply of highly nutritious vegetables and fruits, and improve the resilience of community facing the adverse effect of climate change

**Keywords:** Bio-reclamation of degraded land, indigenous vegetables, women empowerment

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## Public-Private Cooperation in Extension Services - Impact on Agricultural Development in Sub-Saharan Africa

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Different channels and models of agricultural extension services have been implemented in sub-Saharan Africa with modest results in terms of input adoption, productivity and subsequent farm revenue increases. The lack of comprehensive data on agricultural extension services that serve farmers in sub-Saharan Africa makes it difficult to ascertain their contribution to agricultural development over time. Only limited empirical evaluation exist of the impact of different extension services models on farm revenue. The same is true for panel data studies on novel partnerships concerning fertiliser adoption. We fill this gap by analysing the performance of different channels and models of extension services on farm revenue and public-private cooperation on fertiliser uptake in Nigeria over time. Up until the mid-2000s, fertiliser usage was low in Nigeria compared to the sub-Saharan Africa average. Consequently, the Government of Nigeria enacted the Agricultural Transformation Act, which engages private agro-dealers in the procurement and distribution of subsidised fertiliser and improved seeds. For instance, farmers could purchase fertiliser (also from private extension service agencies at market prices and could use e-vouchers issued by the Government to pay for it. The e-vouchers can be accessed by registered farmers via a mobile phone-based electronic voucher system.

Using the 2009/10 and 2012 Living Standard Measurement Study (LSMS) of the World Bank and an ordinary least squared (OLS) regression, we analyse the performance of different channels and models of extension services on farm revenue in Nigeria. Furthermore, the difference-in-difference methodology investigates fertiliser uptake among farmers participating in private extension services prior to and after the implementation of the National Fertiliser Policy and the subsequent policy measure i.e. the e-vouchers.

The results suggest that farm inputs (incl. fertiliser) and on-farm extension visitations positively influence farm revenue. With regard to the on-farm visitations, public extension services compared to private extension services were more effective in terms of revenue generation. Furthermore, procurement of fertiliser by farmers from private extension services has increased compared to the situation prior to the e-voucher programme and this could raise agricultural output in Nigeria the near future.

**Keywords:** Agricultural policy, extension services, farm profitability, fertiliser adoption, Nigeria, sub-Saharan Africa.

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## **Rivalry for Urban Food Markets between Farmers and Pastoralists in the Western Highlands of Cameroon**

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Extensive cattle husbandry has a long tradition in the Northwest Region of Cameroon, in particular amongst its resident Mbororo people. This subgroup of the Fulani ethnicity contributes significantly to the region's supply with beef and, to a smaller extent, dairy products. Many pastoralists still pursue a seasonal grazing strategy by sending their herds from higher-altitude rainy season pastures to lower-lying valleys and transhumance zones during the dry season. Here, however, conflicts with local crop farmers are increasing due to growing human and livestock populations and progressive land-use change from natural and traditional grazing areas to agricultural land. To document these changes and determine the main areas of conflict, six representative Mbororo cattle herds, evenly distributed around the urban centre of Bamenda, were equipped with GPS collars during the dry seasons 2016/17 and 2017/18 and the animals' grazing ranges both in their transhumance and home grazing pastures were delineated. Maximum distances of both zones to the city were taken to define a 70 × 70 km investigation area from where cattle herds directly supply the peri-/urban markets. Within this range, 166 randomly sampled Mbororo cattle keepers were interviewed on subjects such as land ownership, access to grazing and water resources, stocking densities, major challenges in general and farmer-grazer conflicts in particular. Furthermore, interviewees were asked to describe the location of their herds' current and past transhumance zones and corridors. Information were directly registered in digital form to provide a basis for further GIS-based historical land-use change analyses. One third (32.5 %) of the herd owners indicated incidents directly related to farmer-grazer conflicts and farm encroachment a major problem during times of transhumance, and still 23.5 % of respondents mentioned it for their rainy season home grazing areas. At the same time, the pastoralists appeared unprepared for land disputes as none of the respondents owned an official land title for the dry season grazing land, and only 5.0 % held a title for the home grazing area. However, 9.0 % and 19.2 % of the respondents claimed ownership of dry season and rainy season pastures, respectively, by fencing them. Land tenure issues will thus become increasingly important in the future.

**Keywords:** Alliance farming, land tenure, Mbororo Fulani, participatory mapping

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## How Climate-Smart Is Farmer Managed Natural Regeneration? Co-Benefits Leading to Food Security in Niger

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Farmer managed natural regeneration (FMNR) is a practice used on agricultural land to support native trees growth. Although preliminary evidence indicates that FMNR is beneficial for crop-livestock production, additional research is needed to quantify its climate change mitigation (CCM) potential. This study estimated FMNR effects on food security, land productivity and CCM potential, all ingredients of climate-smart agriculture. Field research was conducted in Niger, where we evaluated farm household performance, and estimated their food security status, associated with time since FMNR practice. We tested the hypotheses that i) farmers who practice FMNR achieve higher food security and self-sufficiency than farmers who do not practice; and ii) that these effects are explained through a positive effect of FMNR on farm productivity and income. Analysis of soil C revealed that the implementation of FMNR leads to modest increase in soil organic matter (SOM) limited to the topsoil layers (0–20 cm) compared to sites under normal practice. The positive effect of FMNR on SOM levels decreases with distance from the stem, which is indicative of the positive effect that tree canopy has on SOM storage. Synthetic regression models combining farm, household and FMNR variables show that the FMNR is associated with food security either directly through the total area under wood canopy cover. Our analyses show positive association between FMNR and income, and FMNR and food security and self-sufficiency, which qualifies FMNR as a CSA practice. These associations are direct and indirect, which suggest that a number of positive correlated benefits are derived from FMNR practice.

**Keywords:** Dryland agroforestry, income, mitigation co-benefits, resilience, semi-arid environments, West Africa

## Enhancing Nutritious Food Availability through Promotion of Native Edible Tree/ Shrub Species in Sub-Saharan Africa

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The project “Enhancing nutritious food availability through promotion of native edible tree and shrub species in sub-Saharan Africa (TREEFOOD)” is implemented in Benin, Burkina Faso, Mali and Niger. In West Africa, malnutrition affects more than 18 million children and is considered as a serious constraint to socio-economic development. Despite a high potential for food production, the situation of malnutrition could increase with regard to the high population growth in sub-Saharan Africa. Non-timber forest products (NTFPs) from native tree and shrub species are source of nutrient and food diversification. TREEFOOD aims to contribute to increase food security and fight against malnutrition through sustainable management and improved use of selected native edible tree/shrub species. The project focuses on selected native NTFPs in order to: 1) assess traditional knowledge and practices on them; 2) analyse their biochemical compounds and nutritional value; 3) analyse and develop value chains and improved marketing and processing of products; 4) develop locally adapted propagation methods; and 5) strengthen institutional and innovation capacities of local communities. Field work is conducted in two different agro-ecological zones per country. The project works with farmer-led innovation platforms for improving collection, production, processing and marketing of products from *Adansonia digitata*, *Balanites aegyptiaca*, *Borassus aethiopum*, *Irvingia gabonensis*, *Saba senegalensis*, *Ziziphus mauritiana*. Preliminary results showed a high number of edible trees and shrubs used as food and to reduce malnutrition which varied according to the study villages in the four countries. Up to now, we have documented farmers’ perception of food role, consumption forms, food categories of edible organs, and economic and social use, constraints of the native edible tree/shrub species. Adult Trees and regeneration average density per hectare and species richness in forests and fields are variable within and between agro-ecological zones. The next step will focus on the biochemical analysis and characterisation of the value chain of the main products derived from the target species.

**Keywords:** Agro-biodiversity, food security, innovation platform, native edible tree/shrub, non-timber forest products, sub-Saharan Africa

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## Industrial Wastewater Irrigation Affects Soil Quality in Urban Vegetable Production of Burkina Faso

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Utilisation of industrial wastewater in urban and peri-urban gardens poses risks of contamination of humans, animals, soils and plants. Irrigation with sodic alkaline wastewater is common worldwide and may lower soil productivity especially under semi-arid, hot climatic conditions. Our study reviews literature addressing agricultural use of wastewater with  $> 100 \text{ mg l}^{-1}$  sodium (Na) under semi-arid climates. Findings were compared to those of a case study from urban gardens in Ouagadougou, Burkina Faso. Our aims were to (i) examine to what extent Na in water can induce soil sodicity; (ii) evaluate the effect of industrial wastewater on top- and subsoil sodification in Ouagadougou, and (iii) compare the results of our case study with those reported in the literature.

Soil samples from 45 randomly selected fields were analysed for pH, electrical conductivity (EC) and exchangeable cations. Farmer interviews were used to record information on irrigation and cultivation, including management practices used over the last decade. Wastewater originating from industrial tanneries and beverage producers had pH values from 8.5 to 9.8. Effluents had Na concentrations of 300 to 1200  $\text{mg l}^{-1}$ . Wastewater irrigation induced a reduction in soil quality by increasing soil pH by up to 2 units, increasing EC by 14 % to 500 % and increasing Na up to 28 times compared with the initial value. Both, continuous and short term irrigation with sodic wastewater led to Na accumulation in the soil. Our study further indicated that dissolved Na percolated both vertically and horizontally, thereby contaminating the subsoil and the surrounding non-irrigated area.

**Keywords:** Industrial wastewater, irrigation, sodic soil, urban agriculture

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## Dairy Markets and Distribution Channels in Bamako, Mali

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From August 2017 to March 2018, research about the dairy markets in Bamako, capital city of Mali, was carried out within the BMBF-funded project Urban FoodPlus. Fresh milk and dairy products are nutritious foods that can alleviate certain nutrient deficiencies, especially in food insecure societies of West Africa. While the Food and Agricultural Organisation (FAO) recommends a yearly per capita milk consumption of 62L, Mali remains at a low national average of 10L, and about 25L in Bamako. For this study, 166 milk producing households were successfully interviewed in the urban and peri-urban areas of the metropole. The semi-structured questionnaire included both qualitative and quantitative questions on their household socio-economic characteristics and assets, farm production and management, sales and purchases, institutional factors, and milk marketing strategies. In addition, data on 68 random sale points of dairy products was collected across 18 different neighbourhoods. A total of 103 milk samples were compiled and analysed for physio-chemical components. Results show a median herd size of 40 cattle heads per household, and a low average daily milk production of 3.7 L cow<sup>-1</sup>. For milk quality, 4.1 % was the average fat content, 3.5 % for protein, and only 5 samples were diluted (mean of 11.8 % of water). Average farm-gate price of fresh unpasteurised milk was 380 CFA L<sup>-1</sup> (0.58€). Sale points sold on average 40L per day of fresh pasteurised milk for 560 CFA L<sup>-1</sup> (0.85€). In terms of transformation, neither households nor sale points marketed locally-made cheese or butter, and all yogurts in the city are made with imported milk powder. Transformation is limited to “fènè”, a traditional soured milk product fermented without lactic cultures. Only 14 % of households produced “fènè” for the farm-gate price of 505 CFA L<sup>-1</sup> (0.77€), and almost half of the sale points also sold “fènè” for roughly 590 CFA L<sup>-1</sup> (0.90€). Accordingly, only 30 % of respondents mentioned having access to training related to dairy. Investigating the milk distribution channels used by urban Malian dairy farmers and the fresh milk transformations occurring along the value chain can enable policy makers and entrepreneurs to identify the lacunas of the markets and value addition opportunities.

**Keywords:** Bamako, dairy, livestock, Mali, markets, milk, urban agriculture, value chain

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## Soil and Water Conservation Practices to Combat Impacts of Drought in the Semi-Arid Region of Mali

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Soil and water conservation (SWC) practices like that of erosion control and soil fertility measures were commonly practiced in the semi-arid region of southern Mali since the 1980s. A total of 2562 cotton producing villages benefited from SWC practices and other technological innovations from 1982 to 2000 through the Compagnie Malienne pour le Développement des Textiles (CMDT). Since the year 2000 individual farmers took the initiative to implement SWC practices in their fields. The SWC practices were mainly meant to increase soil water content, reduce farm erosion, and improve nutrient content of the soil, thereby increasing crops yield. Despite such efforts to promote at scale SWC practices, the landscape of southern Mali are still affected by high rates of soil erosion and low crops yield. Data is lacking on previous beneficial SWC practices that could be adapted for wider application. In 2015 and 2016 a field experimentation was conducted in a small watershed in southern Mali to evaluate the biophysical and economic benefits of SWC practices. Results revealed that with the implementation of SWC practices runoff was reduced significantly ( $p$  value 0.005) and soil water content increased with significant variation ( $p < 0.0001$ ) along the soil profile. Temporal variation of soil moisture showed an increase in soil water content by 33 % during the middle of the rainy season and 85 % at the end of the rainy season for fields treated with SWC practices. The increase in soil water content was necessary to meet the consumptive water demand by crops and vegetation in the watershed. The implementation of SWC practices was found to be socially viable with a 20 % more net returns from fields treated with SWC practices.

**Keywords:** Contour bunding, land use and land cover, participatory approach, rainfed agriculture, semi-arid region, shallow wells, soil and water conservation, southern Mali, watershed management



## Potentials of Traditional African Oil Trees for Improving Food Security

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Food oil of good quality is important for health and food security. Women in rural Africa traditionally extract oil from the seeds of numerous native trees, but the potentials are far from fully realised. During two projects, QUALITREE and TREEFOOD, we investigated ethnobotanical knowledge in Mali and Burkina Faso, analysed physiochemical properties of oils from over 30 different native tree species and made a complete literature review of native tree oils from West Africa. Local knowledge about oil production is often good, but in most cases confined to smaller local areas or specific ethnic groups. Screening of oils from native species revealed very good potentials for ameliorated use and production. Examples of highly interesting species are *Adansonia digitata*, *Azelia africana*, *Balanites aegyptiaca*, *Carapa procera*, *Khaya senegalensis*, *Lannea microcarpa*, *Lophira lanceolata* and *Pentadesma butyracea*. The literature review showed that a few species (mainly *Elaeis guineensis* and *Vitellaria paradoxa*) are highly investigated, but for most species, there are few good data about oil properties and ethnobotanical potential. Many published oil analyses from the region are covered with great uncertainty or are directly faulty. There is an extraordinary potential for improving health, food security and economic development in poor communities via increased and improved oil production. Marketing interests of oil includes both local and international markets. However, in many cases tree planting or nature protection in collaboration with local communities are needed to ensure sufficient and continuous oil supplies. Such activities can improve the local biodiversity as an additional advantage of oil production.

**Keywords:** Africa, fatty acids, food security, traditional oils

## Planting Pit Size and Farmer's Management Practices Explained Survival and Growth of Planted Seedlings in Contrasting Land-Use Systems in Mali

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Successful establishment and growth of trees in degraded landscape is an important factor in efforts to land restoration in degraded dryland. In Mali as in most the Sahelian countries, large tree plantations have started after the severe drought of the 70s. The high cost of plantation associated with low survival and low productivity has been the main impediment to large success. Planted trees performance in rural settings are affected not only by seedling related traits and environmental conditions, but also by the management practices of farmers who plant, own, maintain, and expect benefit from these trees. This paper based on multi-environment trials of two planting pit sizes (small size planting hole [30 × 30 cm] vs. big size planting hole [60 × 60 cm]), studies the survival and growth of young improved *Ziziphus mauritiana* cultivars planted by 1600 volunteer farmers from three contrasting regions Mopti, Sikasso and Ségou in Mali. We used the so-called planned comparison approach, to explain planted tree success one year after out planting, with regards to the initial characteristics of the trees, the biophysical environment and the farmers specific context. We use a probit model to predict tree survival, and a linear regression model to predict tree growth rate. Our results suggest that biophysical and socio-economic factors are all important in explaining the success (survival and growth) of young planted trees. The following variables are positively related to tree success (survival and/or growth): planting pit depth, median household income, planting location, farmers' motivations and tree planting experience, mulching, and a watering regime. The results from this study though limited in time, highlight the fact that more comprehensive evaluation that combined biophysical environment and social factors related to the farmers are needed to explain success in plantation.

**Keywords:** Drought resistance, growth, planting material, semi-arid agro-ecosystem, soil moisture, survival

# Food and technology

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# Local food systems and human nutrition

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## Role of Biodiversity in Improving Dietary Diversity and Quality of Complementary Foods for Infants and Young Children in Southern Benin

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FoodAfrica is a research for development programme coordinated by MTT Agrifood Research Finland and financed by the Finish Government and CGIAR, aiming to improve food security in West and East Africa. Having started in 2012, different projects have been implemented in six African countries. In southern Benin, where almost a third of children are malnourished, a 6-year initiative examined ways in which local food sources could be better used to nourish infants and young children.

A cross-sectional survey was performed in two communes of the Mono Department, Southern Benin. Over 1,200 households were interviewed regarding food and nutrition security, dietary intakes of infants and young children (6–23 months), and agrobiodiversity (ABD). Based on this information, feeding practices were studied, dietary gaps identified and ABD contributions calculated. In addition, over 300 recipes for complementary foods were collected out of which 20 were optimised via linear programming by adding ingredients from locally available biodiversity. Out of these 20 recipes, five were field tested with mother/child pairs for acceptability. Culturally sensitive nutrition education materials such as videos, posters, a food calendar and a recipe booklet were developed promoting good feeding practices based on local food biodiversity.

The vast majority of the households (80 %) were classified as food insecure. The prevalence of the small children's minimum dietary diversity, minimum meal frequency and minimum acceptable diet accounted for 60 %, 71 % and 46 %, respectively. The ABD surveys documented 146 plant and 148 animal species known as food sources. However, only 47 food products were consumed. Local biodiverse foods contributed between 49 % (calcium) to 98 % (Vitamin A) of total micronutrient intakes. The timing for the introduction of complementary foods was in most cases (78 %) incorrect. The children's micronutrient adequacy correlated with the caregiver's education.

The results confirm the richness of local food biodiversity that can be used for food and nutrition security. The fact that micronutrient adequacy correlated with caregiver's education shows the potential of nutrition education for improved feeding practices. This research has helped to fill gaps in nutrition education materials both for caregivers as well as for community health workers and agricultural extension agents.

**Keywords:** Agrobiodiversity, Benin, complementary feeding, nutrition, nutrition education, nutrition education materials

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## **African Indigenous Vegetables Contribution Towards Food Security and Safety in Kenya: A Meal Cultures Perspective**

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Food insecurity and micronutrient deficiencies have been persistent issues in Kenya that are averting the achievement of the sustainable development goals. One of the existing strategies to alleviate the situation is the use of African indigenous vegetables (AIVs). Notable for their high levels of bioactive compounds, AIVs have been recommended as beneficial for nutrition and health. Besides, some species grow naturally and their minimal requirement for fertilisers and pesticides contributes to food safety. AIVs were part of the meal culture of most Kenyan households during the pre-colonial times. However, during the colonial times, there was a change in the meal cultures resulting from introduction of exotic vegetables. Thus, AIVs were neglected but as a result of concerted efforts by researchers and other stakeholders increased consumption of the vegetables has been noted. Consumption at the household level, however, still faces a number of challenges. Several studies have been conducted on production and marketing of AIVs, but preparation and cooking, and thus food safety at the household level still remain a missing link. The aim of the paper is to present the results of the HORTINLEA research project ‘Meal Cultures in Market Trends and Consumption Habits’. The objective of this research was to establish factors that influence the preparation, cooking and consumption of AIVs in Kenya. The research questions were: Which factors determine AIV consumption and how do meal cultures affect consumption trends of AIVs? A qualitative approach was used and the innovative concept of meal cultures by Teherani-Krönner employed. Research areas were Nairobi (urban), Nakuru (peri-urban), Kakamega (rural). The sample size was 70 (expert interviews, focus group discussions and cooking along interviews) conducted in 2015–2017. Results showed that eight different AIVs were consumed regularly in households. Preparation, cooking and eating of AIVs depended on ethnicity, availability of resources and age. Water, which is key to food safety, was found to influence consumption. Preparation and cooking of AIVs was highly gendered. The study concluded that AIVs could contribute to food and nutrition security in Kenyan households if the meal cultures concept was applied in the investigation of AIV consumption and food safety.

**Keywords:** African indigenous vegetables, food safety, food security

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## Development and Implementation of Insect-Based Products to Enhance Food and Nutritional Security in Sub-Saharan Africa

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With a growing world population, increasingly demanding consumers, and a limited amount of agricultural land, there is an urgent need to find alternatives to conventional meat products. Livestock production is a leading cause of anthropogenic-induced climate change. More sustainable diets are needed, with reduced meat consumption or the use of alternative protein sources. Insects are promoted as human food and animal feed worldwide. In tropical countries, edible insects are harvested naturally, but over-exploitation, habitat changes, and environmental contamination threaten this resource. Therefore, sustainable harvesting practices need to be developed and implemented. The consumption of crickets (e.g. the house cricket *Acheta domesticus*), the longhorn grasshopper (*Ruspolia differens*), and a variety of saturniid caterpillars (e.g. *Imbrasia zambesina* and *Cirina forda*) is part of the food culture of some communities in Kenya and Uganda and constitutes 5 – 10 % of protein intake of the rural and urban populace. For many, trade in edible insects is a major source of income and considerably contributes to livelihood improvements. Recently chitin (the main component of the arthropod exoskeleton) is attracting considerable attention due to its role in enhancing immunity, promoting growth of beneficial bacteria and inhibiting the growth and activity of pathogenic microorganisms. Furthermore, its consumption could improve the health of rural communities across Africa and beyond. Therefore the potential of the insects as a source of micronutrients, e.g. minerals like zinc and iron or vitamins, to combat hidden hunger is investigated. EntoNUTRI - a 3-year project - is a complementary partnership of icipe, University of Bonn, University of Hohenheim's Food Security Centre (FSC), and national agricultural research systems (NARS) from Kenya and Uganda to enhance food and nutritional security through the use of insects as food and sponsored by the Federal Ministry for Economic Cooperation and Development (BMZ). Our findings suggest major environmental advantages of insect farming compared to livestock production: (1) limited land and water consumption; (2) lower greenhouse gas emissions; (3) higher feed conversion efficiencies; (4) transformation of low-value organic by-products into high-quality food or feed. However, edible insect species intended for production should be screened for risks to humans, animals, plants, and biodiversity.

**Keywords:** Edible insects, food security, icipe, insects farming, Kenya, Uganda

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## How to Fill Harvest and Nutrient ‘Gaps’ through Locally Available Tree Foods?

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Tree foods including fruits, leafy vegetables, nuts, seeds and edible oils present locally available and traditionally used foods to diversify staple diets. To better incorporate these foods into food systems and thereby addressing challenges of seasonal food availability, the World Agroforestry Centre developed a methodology for selecting ecologically-suitable and nutritionally-valuable food tree species for production on farms. In addition to filling harvest ‘gaps’ the portfolio addresses certain nutrient ‘gaps’ in a site. To do so, food tree species identified in harvest calendars are mapped with nutritional data. Food composition data play a key role in linking agriculture to nutrition, but unfortunately information on the nutrient composition of many species, particularly indigenous and wild species, are absent due to a lack of research. This could mean that food tree species rich in micronutrients are overlooked in development planning, projects and policies. Hence, as a first step food composition data from scientific articles and food composition tables were compiled, standardised and aggregated, following international standards on food composition from FAO/INFOODS. Thereafter, mean values of recommended nutrient intake data (RNI) were calculated based on FAO/WHO references. In a third step, the percentage of RNI of iron, zinc, folate, vitamin C and vitamin A provided by species were calculated. To simplify the nutrient content information for the portfolios, fruits and vegetables were scored for whether they are a high source (+++), source (++) or low source (+) for the respective nutrient. The thresholds are based on FAO/WHO food labelling standards and own adaptations. Information on the nutrient content of the selected foods will be available in an open access database and in a simplified form to support decision-making by key stakeholders in the selection of ecologically suitable and nutritionally value tree species for cultivation. The development of fruit tree portfolios by using locally suitable species and their nutrient content information and seasonal availability is a sustainable food based approach to address micronutrient deficiencies by increasing the quality of local diets. Moreover, the food composition data compiled for food tree species provides a necessary repository for prioritising domestication programs to mainstream available nutritious foods.

**Keywords:** Food composition, food tree species, food-based approach, hunger gap, indigenous species, micronutrients, nutrition, seasonality

## Real-Time Dietary Assessment Using a Validated IT-Based Approach within a Ghanaian Setting

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Meeting dietary needs represents a key element to guarantee food security. However, appropriate solutions for fast and precise assessments of dietary energy and nutrient intakes are still not available. This becomes particularly evident, if accurate pictures on individual-level must be generated. Therefore, this study illustrates the calculator of inadequate micronutrient intake (CIMI) approach: a programme evaluating dietary intakes in real-time based on individual dietary patterns.

Quantitative data on food consumption of adults in reproductive age and children under-five were obtained by a cross-sectional nutrition survey conducted in Southern Ghana. Food frequency questionnaire findings and food composition tables were used for the identification of region-specific food groups forming the basic structure of CIMI. Subsequently, the programme was validated by correlating and plotting results obtained through the analysis of 24h-recalls with CIMI and a standard nutrition software (NutriSurvey).

Pearson correlations ( $r \geq 0.75$ ) and Bland-Altman plots (agreement limit:  $\pm 1.96SD$ ) indicate the comparability of the two dietary assessment programs and thus, the validity of CIMI. Due to the user-friendly data entry system consisting of region-specific food groups and the real-time survey analysis, CIMI proves to be fast while considering individual dietary patterns. For Ashanti region, diets were strongly characterised by the consumption of starchy staples (54 %), however, in comparison with the recommended nutrient intake (RNI) of the World Health Organisation (WHO), dietary needs were largely met in all sub-population groups. Virtually no dairy products were consumed, resulting in an overall poor dietary calcium intake ( $29.9 \pm 13.9$  %RNI). In addition, generally low intakes of riboflavin were observed covering  $72.4 \pm 42.3$  %RNI. Dietary iron coverage of women had to be considered as inadequate ( $67.4 \pm 39.3$  %RNI). Further data for Brong-Ahafo, Central and Eastern region are currently under analysis and will be presented at the conference.

A fast and precise IT-based approach for individual dietary energy and nutrient intake assessments was successfully developed and validated for a Ghanaian setting. As such, the programme represents a first step towards the collection of large-scale datasets on individual dietary intakes that will serve as a profound basis for stakeholders to recommend appropriate local food sources and proportions for improved diets.

**Keywords:** CIMI, dietary assessment, food security, Ghana, micronutrients

## Food and Nutrient Gaps of Smallholder Farming Households in Rural Northern Ghana

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Food-based dietary guidelines (FBDGs) provide guidance to policy makers, the private sector and consumers to redesign food systems and to improve diets of vulnerable populations. As FBDGs are based on the actual dietary patterns and their costs, it is assumed that the recommended foods are available, affordable and acceptable. Using quantitative dietary intake data of young children in rural Ghana, we developed FBDGs and studied whether these are supported by the diversity and quantity of household's foods production. We found that 40 % of Ghanaian infants and young children were stunted and their nutrient intakes were far below the required amounts. The developed FBDGs for household level were on average not able to sufficiently cover the requirements for fat, calcium, iron, vitamin A, vitamin B12 and vitamin C. This implies that in case of adoption of these FBDGs the requirements for these nutrients will not be met. In addition, the household's nutrient needs and food needs (according to the developed FBDGs) were only marginally covered by their own food production. Over half the households had insufficient calcium, vitamin A, vitamin B12 and vitamin C to cover their needs. About 60 % of the households did not cover their required amounts of grains and legumes and none of vegetables. Further analysis of the food gaps at district and national level showed grain requirements were covered at both levels (267 % and 148 %, respectively); legume only at district level (268 %) but not at national level (52 %); and vegetable not at both levels (2 % and 49 %, respectively). Thus this study show that food availability does not support the adoption of FBDGs in rural northern Ghana. Diversifying crop production is often mentioned as a potential solution for increasing the diversity of foods available and thereby increasing dietary diversity of rural low and middle income country populations. We found that household's food production diversity was indeed positively related with household's food and nutrient coverage but not with the child's dietary diversity and nutrient adequacy. Our results suggest that the promotion of FBDGs through behaviour change communications activities alone is insufficient to lead to improvements in diets.

**Keywords:** Crop diversity, dietary adequacy, dietary diversity, food gap, food-based dietary guidelines, Ghana, nutrient gap, smallholder farm households

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## Determinants of Nutrient and Dietary Gaps in the Changing Food Systems in Nigeria

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Improved nutrition is thought to have multiplier effect across the Sustainable Development Goals (SDGs). Yet, much like other low and middle income countries, achieving the SDGs in Nigeria will be challenged by co-existence of undernutrition, micronutrient deficiencies and growing rates of overweight and obesity in the population. The food environment is also changing both in urban and rural areas, which is likely to create new nutritional challenges while opening opportunities. This requires a dynamic approach to identify entry points for intervention. However, a lack of food consumption surveys specifically designed for food and nutrition research from representative samples remains a major constraint to studying nutrient and dietary gaps. Previous studies mainly rely on cross-sectional observations and have limited scope in terms of: capturing the dynamics in both rural and urban food systems, their geographic coverage and indicators of diet quality (e.g. they often use caloric intake with no or limited information on the content of micronutrients in the diet). We overcome many of these limitations by making use of multiple round Living Standard Measurement Surveys (LSMS-ISA) in Nigeria. These are large national and sub-national representative surveys, and they are a rich source of information from the food systems perspective as nutrient and dietary intake can be linked to different aspects of the food systems. We first estimate nutrient and dietary gaps for the individual from household data, in terms of adult female equivalent which proxies intrahousehold distribution of food. We then employ panel data econometrics to identify factors that may explain observed differences in nutrient and dietary gaps over time and space.

**Keywords:** Dietary gap, food systems, Nigeria

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## **Baobab as a Natural Micronutrient Dietary Complement for Nutrition Security: A Research Undertaking by the Baofood Project**

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Micronutrient malnutrition attacks more than 2 billion people worldwide. Many suffer from multiple deficiencies. Iron deficiency anemia affects 1.62 billion people and has severe implications on the physical and cognitive development of children. Zinc is important for growth and immunity because of its involvement in DNA and protein synthesis; 1.3 billion people or 17 % of the world's population is at risk of zinc deficiency. A recent study (2015) based on food supply suggests that 3.5 billion people are at risk of rickets and osteomalacia due to calcium or a combination of calcium and vitamin D deficiency. It is estimated that 90 million children <5 years and 22.24 million pregnant women suffer from subclinical vitamin A deficiency leading to lowered immunity and increased risk of mortality in children.

Forest trees are natural and traditional supplement to staple diets. Baobab represents one of those that sporadically supplements rural diets and serves as traditional medicine. It has therefore attracted attention for compositional investigation. Baobab leaves contain 5.4 g calcium per 100 g DM, 10–18 times more calcium than in the foodstuffs commonly known as calcium-rich (e.g. milk, green-leafy-vegetables and pulses). The pulp contains 318 mg/100 g, more than 2-times the calcium concentration in milk and 3–4 times that in leafy vegetables.

The magnesium content (339 mg/100 g dry sample) of the leaves and that of the seeds (402 mg/100 g dry sample) are 2.35 and 2.8 times that of pulses (144 mg/100 g); and pulses are commonly known as rich sources of magnesium. The leaves and seeds of baobab have better concentration of zinc, (4 and 5 mg/100 g respectively), than that of legumes (2.4 mg/100 g) and beef (1.6 mg/100 g).

Baobab leaves contain on the average 65 mg Fe/100 g sample, more than five times the level present in the richest conventional foodstuffs (11.9 mg Fe/100 g legume) and more than 15x that in meat (4.2 mg/100 g). The pulp has moderate iron concentration (about 4 mg/100g) that on the average is comparable to the amount in beef. The combination of its moderate iron and rich vitamin C content, about six times more than that in citrus fruits, makes the pulp a desirable complement of a daily diet.

**Keywords:** Baobab, deficiency, micronutrients, natural supplements

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## Micronutrient Adequacy in Diets Consumed by School Children from Farming Communities of Tanzania

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School children are vulnerable to micronutrient deficiencies. Micronutrient deficiencies during this period may lead to retarded growth, poor cognitive development, anaemia and increased risk of infections. This study aimed to assess the adequacy of zinc, iron and vitamin A, in diets consumed by school children aged 5–10 years in Chamwino and Kilosa districts, Tanzania.

In a cross-sectional study, 666 children aged 5–10 years were randomly recruited. Dietary assessment was conducted using a quantified 24 hours recall and a food frequency questionnaire. Nutri-survey software was used for analysis of nutrient intake. Serum levels of zinc, iron and vitamin A were determined using enzyme-linked immunosorbent assay and spectrophotometric methods. Household dietary diversity score (HDDS) was also derived. Data are presented as means (SD) and prevalences and compared using ANOVA, and chi-squared test.

The median caloric intake was 898 Kcal, 81 % of the children in the study did not met the Recommended Daily Intake (RDI) for energy. The median dietary intake of iron was 11.5 mg day<sup>-1</sup> and was inadequate for 26 % of the children. The median dietary intake of zinc was 4.9 mg day<sup>-1</sup> with 95 % of the children not meeting the RDI. The median dietary intake of vitamin A was 320 µg RE day<sup>-1</sup> and was inadequate for over 62 % of the children. The prevalence of anaemia, low vitamin A status and zinc deficiency among study children was 42.9 %, 65.4 % and 32.8 % respectively. Iron deficiency prevalence was 27.8 %. Anaemia, low vitamin A status and zinc deficiency, which may be partly linked to the poor dietary intake was prevalent among children in the study area. The overall mean HDDS was 4.8 ± 1.8. The least consumed food groups in both districts were eggs, milk products and meat/organ.

The consumed diets had limited diversification coupled with inadequate intake of iron, zinc and vitamin A, leading to poor micronutrient status. This study recommends consumption of pro vitamin A rich vegetables/fruits and animal based foods in order to improve children's micronutrient status in the study villages.

The financial support of Scale-N project by the German federal ministry of food and agriculture (BMEL) is highly acknowledged.

**Keywords:** Dietary intake, iron, school children, vitamin A, zinc

## Dietary Diversity and Consumption of Foods from Different Food Groups among Small Holder Women Farmers in Kenya, Malawi and Uganda

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Inadequate dietary intake among women of reproductive age remains a challenge in some countries of sub-Saharan Africa. This study compared the dietary diversity and consumption of foods from different groups among women in three African countries.

Cross-sectional agriculture-nutrition baseline surveys were conducted in Teso sub-county (Kenya), Kapchorwa District (Uganda) and Lilongwe District (Malawi) between May - November 2016, targeting 1263 farm households with children aged under five years. All three study regions relied on small holder maize farming. Semi-structured questionnaires were used to assess demographic and socio-economic characteristics. A Minimum Dietary Diversity Score for Women (MDD-W, max 10 groups) was calculated based on a 24h-recall. Anthropometric measurements were taken to calculate body mass index (BMI).

Mean (SD) BMI was similar in all three countries (Kenya:  $23 \text{ kg m}^{-2} \pm 4$ ; Malawi:  $23 \text{ kg m}^{-2} \pm 3$ ; Uganda:  $23 \text{ kg m}^{-2} \pm 4$ ). Mean number of food groups consumed differed significantly between the countries  $4.2 \pm 1.2$  (Kenya),  $3.9 \pm 1.4$  (Malawi),  $4.3 \pm 1.2$  (Uganda), ( $p \leq 0.05$ ). The proportion of women who achieved MDD-W in Uganda, Kenya and Malawi were 44.5 %, 41.2 % and 33.5 %, respectively. “Grains, white tubers and plantain” was the most consumed food group (Kenya: 100%; Malawi: 93%; Uganda: 100 %). There were great differences in the proportion of women who consumed foods from other food groups. While the least consumed food group in Kenya was nuts and seeds (6 %), eggs were least consumed by women in Uganda (5 %) and Malawi (<1 %). Only one in 10 women in Kenya (11 %) and Uganda (9 %) consumed vitamin A rich fruits and vegetables in contrast to 34 % in Malawi. Animal source food consumption was twice to three times higher in Kenya compared to Malawi and Uganda (Kenya: 64 %, Malawi: 28 %, Uganda: 21 %).

The low proportion of women who achieved MDD-W indicates a high risk for micronutrient deficiencies in all three regions. Region specific agriculture and nutrition interventions are needed to improve the availability and consumption of the different non-staple foods.

The study was funded by the BLE with support from the BMEL.

**Keywords:** Dietary diversity, food security, hidden hunger, nutrition

## Grain Legume Cultivation and Children's Dietary Diversity in Smallholder Farming Households in Rural Ghana and Kenya

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Boosting smallholder food production can potentially improve children's nutrition in rural sub-Saharan Africa through a production-own consumption pathway and an income-food purchase pathway. Rigorously designed studies are needed to provide evidence for nutrition impact, but are often difficult to implement in agricultural projects. Within the framework of a large agricultural development project supporting legume production (N<sub>2</sub>Africa), we studied the potential to improve children's dietary diversity by comparing N<sub>2</sub>Africa and non-N<sub>2</sub>Africa households in a cross-sectional quasi-experimental design, followed by structural equation modelling (SEM) and focus group discussions in rural Ghana and Kenya. Comparing N<sub>2</sub>Africa and non-N<sub>2</sub>Africa households, we found that participating in N<sub>2</sub>Africa was not associated with improved dietary diversity of children. However, for soybean, SEM indicated a relatively good fit to the *a posteriori* model in Kenya but not in Ghana, and in Kenya only the production-own consumption pathway was fully supported, with no effect through the income-food purchase pathway. Results are possibly related to differences in the food environment between the two countries, related to attribution of positive characteristics to soybean, the variety of local soybean-based dishes, being a new crop or not, women's involvement in soybean cultivation, the presence of markets, and being treated as a food or cash crop. These findings confirm the importance of the food environment for translation of enhanced crop production into improved human nutrition. This study also shows that in a situation where rigorous study designs cannot be implemented, SEM is a useful option to analyse whether agriculture projects have the potential to improve nutrition.

**Keywords:** Children, dietary diversity, Ghana, Kenya, legume production, SEM analysis

## **Willingness and Knowledge of Nepalese Mothers to Improve Babies' Diet to Upgrade their Nutritional Status**

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Food insecurity and child malnutrition are two of the most prevalent problems in Nepal. Among several factors, intake of adequate and nutritious foods needs to be emphasised to counteract this situation. Inadequate feeding practices are a major factor contributing to the situation. Thus, the aim of this study was to determine the knowledge and willingness of mothers towards upgrading the nutritional status of their babies by adapting their feeding practices. The study was conducted in Kathmandu, Nepal in February and March 2018. Mothers with children under the age of three were considered for the survey. The data were analysed using the SPSS software to predict the effects of various independent variables on health aspects of babies and their mothers' knowledge on food nutrients to improve the nutritional status.

Analysis indicated that there were strong negative correlations between educational level of mothers and the number of children ( $p < 0.05$ ). Those mothers who were socially active and discussed on babies' diet and nutrition were found to feed their babies additional amount of fruits and vegetables. Nevertheless, 33 % children were found to be underweight and 9 % children mostly suffering from fever and common cold. A positive correlation was found between the education level of mothers and providing various kinds of foods to the children compared to other factors for preventing malnutrition. However, there were no significant associations between ethnic group, age of mothers and feeding practices. Most of the mothers were intensely willing to change their feeding practices to uplift their babies' health status. However, well-educated mothers had rudimentary information on dried fruits and vegetables nutrient aspects and, thus, rarely consumed themselves or fed to their babies. Thus, an integrated approach that spreads the information on distinct types of foods such as incorporation of fruits and vegetables, dried fruits and nuts, knowledge of optimal nutrition practices, and adequate maternal nutrition, seems to be needed to upgrade the nutritional and to maintain a balanced health status of children in Nepal.

**Keywords:** Awareness, feeding practices, health problem, infants, Nepal

## What Dimensions of Women's Empowerment Matter for Nutritional Outcomes? Evidence from Africa and Asia

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Although linkages between increasing resources controlled by women and nutrition are well established, the linkages between women's empowerment and nutrition have been more difficult to quantify owing to the difficulty of measuring empowerment. This paper conducts new empirical analysis using the Women's Empowerment in Agriculture Index (WEAI), based on large scale surveys in six countries in Africa and Asia, to identify which dimensions and indicators of women's empowerment matter for different diet and nutrition outcomes. We use data from Feed the Future population-based surveys from Bangladesh, Nepal, Cambodia, Ghana, Mozambique, and Tanzania and model the relationship between nutritional outcomes at the household and individual level and women's empowerment in agriculture. Household-level outcomes include the household hunger score, household dietary diversity, and household calorie availability. Women's outcomes include dietary diversity and body mass index (BMI), while child outcomes include indicators of infant and young child feeding (IYCF) practices, dietary diversity, and anthropometric measures.

We find that higher women's empowerment scores and greater household equality (a smaller gap between men's and women's empowerment scores) are almost always associated with better nutritional outcomes. Across countries, higher women's empowerment is also associated with children's nutritional outcomes. Cultural preference for boys over girls is evident in Bangladesh, Nepal, and Ghana; increased women's empowerment is often associated with worse girls' anthropometric outcomes relative to boys. Improved nutrition is not necessarily correlated with being empowered across all empowerment domains, indicating the possibility of tradeoffs. In Nepal, control over incomes is associated with higher women's BMI, but if intensifying participation in agriculture increases workload, then both maternal and child nutrition could be at risk.

The WEAI can be used to identify policy and programming priorities by disaggregating the contribution of each indicator to women's disempowerment. Whenever addressing a top contributor to disempowerment is strongly associated with improvement in several nutritional outcomes, interventions targeting these top contributors to disempowerment could potentially be very cost-effective.

**Keywords:** Dietary diversity, infant and young child feeding, maternal and child nutrition, time use, women's empowerment in agriculture

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## Does Gender-Sensitive Agricultural Intervention Improve Food Security and Profit Efficiency?

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Sweetpotato (*Ipomoea batatas* L.) is an important staple food crop in Rwanda. This study analysed the impacts of gender-sensitive sweetpotato based intervention on food security, food consumption, and profit efficiency; by applying stochastic profit frontier, propensity score matching (PSM), and endogenous switching regression (ESR) models. The study is based on the data collected from 846 households from rural Rwanda, in 2014. The data contains 39 % beneficiaries, 37 % spill-overs, and 24 % control households.

The finding suggested that on average female headed households were less educated, older, own fewer livestock, less likely to participate in sweetpotato marketing, less likely to be involved in informal business, and more likely to be food insecure than male-headed households. Gender-sensitive agricultural intervention increased food consumption scores by 25 and 23 points ( $p < 0.001$ ), for female and male headed households, respectively; and it has reduced the food insecurity of female and male headed households by 35 % and 53 %, respectively. Average level of profit efficiency in sweetpotato production system is 55%; profit efficiency of female beneficiary, and female spill-over is found to be 3.5 %, and 5 %, higher than that of control male households, respectively. The profit efficiency of participant households was 64 % compared to 20 % of the control. It is indicated that food security and food consumption score were positively and significantly ( $p < 0.05$ ) associated with head education, number of sweetpotato varieties planted, participation in informal business, and livestock ownership; and negatively with household size.

It is concluded that gender-sensitive agricultural intervention increased profit efficiency, food security, and food consumption. Furthermore, to achieve the goal of gender-equitable changes in livelihood through agricultural intervention, it is crucial to design programs, policies, and projects explicitly targeting the women; if designed with special attention to women's need, agricultural intervention, can enhance food security, food consumption, and profit efficiency of the poor and disadvantaged households.

**Keywords:** Biofortified crops, food consumption, food security, gender-sensitive intervention, Rwanda

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## Breeding Cooking Bananas: Do Men and Women's Trait Preferences Matter?

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Cooking banana ('Matooke') is an important food staple that supports 17 million Ugandans. Banana productivity is declining due to many factors including pests and diseases. Breeding new varieties offers feasible strategies to address such constraints. However, ensuring that breeding meets the numerous desirable attributes of the end-users is complex. Where improved varietal attributes fail to meet the needs of the end-users, low uptake and adoption ensues. Women and men may have diverse preferences for varietal characteristics because of differing production objectives, norms and values. A study was thus conducted to understand important cooking banana traits preferred by men and women value chain actors. The study sought to determine how the preferred traits shape acceptability of selected cooking banana varieties in central Uganda. Data were collected using sex-disaggregated focus group discussions, key informant interviews and a survey of 174 respondents (87 male and 87 female principle household decision makers). Two sensory evaluation exercises of promising and released hybrids banana varieties were conducted. Results indicated that the traits driving acceptability of cooking banana could be categorised into: traits that enhance (i) production, (ii) food quality, and (iii) marketability. Both men and women end users selected food taste as the most important trait determining acceptability of a cooking banana variety. Although most traits were equally appreciated by both men and women, men showed an inclination towards production and market related traits such as tolerance to drought and poor soil, bunch size, maturity period and shelf life. Women on the other hand appreciated food quality traits such as flavour and colour of the cooked food. We recommend redesigning the banana breeding pipeline to prioritise the gender differentiated attributes so as to deliver varieties that meet the preferences and needs of men and women end users. Since both adult men and women cooking banana consumers are not willing to compromise on the food quality traits, the 'Matooke' hybrid ideotype could be redefined to prioritise traits associated with marketability and quality of the cooked food.

**Keywords:** Breeding, cooking bananas, food quality, trait preferences, Uganda

## Diversity, Use and Consumers' Acceptance of Local Banana Cultivars in Ucayali, Peru

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Bananas (*Musa* spp.) constitute a large part of local food basket in many tropical countries. Some cultivars also possess medicinal properties or help to prevent vitamin A deficiency. This form of hidden hunger is still a problem in Latin America, but can be precluded by consumption of enough provitamin A rich food, such as dark leafy vegetables or orange/red fleshed fruits, including certain *Musa* cultivars. Though banana is a crop with high intraspecific diversity, locally used cultivars in many regions have not been characterised so far in terms of morphology, mode of use and consumers' acceptance. The study was conducted in Pucallpa, the administrative centre of the Ucayali region, located in the Peruvian Amazon. The Ucayali region represents one of the most important banana production areas in Peru. A survey of seven main retail markets in Pucallpa was performed in order to inventory all widely available *Musa* cultivars. All cultivars were morphologically characterised using previously published descriptors and their fruit pulp to peel ratio was calculated. Subsequently, the vendors and customers were interviewed to document local knowledge including vernacular names, modes of preparation and use patterns of each cultivar. Sensorial properties and overall acceptance of dessert type bananas were evaluated by local consumer panel.

In total 11 cultivars were documented including 5 cooking ('Bellaco', 'Campeón', 'Común', 'Mamaluca', 'Sapucho') and 6 dessert type bananas ('Capirona', 'Isla', 'Manzano', 'Muquicho', 'Rojo', 'Seda'). According to our best knowledge, one of the cultivars investigated has been newly documented in Peru. The highest pulp to peel ratio was found in dessert cultivars 'Muquicho', 'Manzano' and 'Seda'. Performances of overall acceptance were positively correlating with pulp sweetness, which indicates its impact on consumers' choices when compared to other characteristics studied. Moreover, orange-fleshed cultivars such as 'Rojo' and 'Isla' should be further studied as potential sources of provitamin A rich food.

**Keywords:** Human nutrition, intraspecific diversity, *Musa*, sensorial properties, traditional knowledge



## Psychological Food-Related Well-Being in a Diaspora Situation

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Food is more than just nutrients and has emotional and symbolic functions. Therefore, food has recently been considered an avenue for helping refugees to resettle and integrate into their new communities. For refugees, food is central for going back to their roots and for building new relationships within the host society. This paper presents an in-depth investigation of refugees' well-being in a food context from a psychological perspective, as they are confronted with a new food environment and forced dietary changes. Following a positive psychology framework of well-being, a qualitative content-based analysis was conducted to analyse 34 in-depth interviews with Syrian refugees residing in Stuttgart, Germany. This study revealed that participants have a strong affinity to their past food-related life and a continuous comparison between what they are used to and what is currently available to them in the new food environment. They have a positive relationship to food, where food plays a comforting role or is used as a way to mentally block themselves against their thoughts and worries. Moreover, participants have loose autonomy and weak environmental mastery over food choices, especially during the war, migration journey, and the temporary settlement in initial reception centres. They expressed their desires, which lacks motivation and guidance, to learn and improve their dietary behaviour in order to enhance health. The insights gained from this research are useful to have a better understanding of the challenges faced by refugees and to inform strategies on how to enhance refugees' integration through food and improving their overall well-being.

**Keywords:** Autonomy, positive psychology, refugees, well-being

## DEVCO Nutrition Commitments and its Discontents

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The European Union is a major player in the field of nutrition in the context of international development cooperation. The major target of this research project is the detection of the factors determining the geography of the EU international cooperation and development (DEVCO) nutrition commitment and disbursement. Due to the limited data on nutrition investments the project relies on the data of 2012 and 2013. Methodologically the project relies on the evaluation tools provided by Scaling Up Nutrition Principles (SUN Methodology). These enable classification of the projects in nutrition specific and unspecific ones. All the results of the project are based on the nutrition specific projects.

There is a huge gap between countries regarding nutrition investments per stunted child. Analysis of the average DEVCO nutrition commitment per stunted child in each country over the last two years further shows that DEVCO's nutrition investments are unevenly distributed over the countries.

The data shows that DEVCO's nutrition commitments over the last two years have only been weakly linked to countries with the highest numbers of stunted children. Taking the top ten recipient countries of DEVCO nutrition commitments, it can be seen that the countries receiving the highest commitments are not the countries with the highest number of stunted children.

Stunting rate, in contrast to the absolute number of stunted children and regional dummy (sub-Saharan Africa), are the only statistically significant determinants of the country-specific DEVCO nutrition investment per stunted child (IV-OLS estimation). The estimation suggests that there is even a slightly negative association between the number of stunted children and nutrition investment per stunted child. The results suggest that there is a need for a better coordination of the geography of the DEVCO nutrition investments which would result in a better and efficient coverage of the investments in reducing malnutrition.

**Keywords:** DEVCO nutrition commitments, scaling up nutrition, stunting rate, sub-Saharan Africa

## **Sustainability Labels for Food Products: A Literature Review on Consumer's Behaviour, Challenges, and Opportunities**

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Sustainability labels first burst between the 1980s and the early 1990s as a method to increase transparency along the food chain and provide consumers with information in order to encourage sustainable consumption. Since then, a proliferation of sustainability labels has occurred, with around 465 Eco labels registered nowadays, among which 148 belong to the food production sector. Nevertheless, even if sustainability labels are commonly believed to be an appealing initiative to foster sustainability in agriculture, they face a number of challenges. The different perceptions of the definition of sustainability, the absence of a common framework, and the recent increase of new labels might limit their understanding and use among consumers and, therefore, the ability to enhance food security and food safety.

The objective of this study is to analyse through a literature review how consumers behave towards sustainability labels from an economic approach and to identify which are the factors that influence consumers' decisions. The analysis shows that understanding and concern about sustainability are critical to determining the consumer's use of labels. Additionally, the use of these labels seems to face challenges from different sources, which might be overcome with new strategies, such as creating a common framework and implanting labels that are easier to understand and incorporate several dimensions of sustainability. The study is divided into three main sections. The first one deals with a general overview of the origin, scope, and classification of sustainability labels for food products. The second section aims to analyse from an economic perspective the consumers' behaviour towards sustainability labels for food products. In the third section, the main challenges of sustainability labels are discussed and one alternative for integrating the framework and scope of sustainability labels is briefly introduced.

**Keywords:** Consumer behaviour, food production, sustainability labels

## Consumption Intensity and Production Constraints of Indigenous Vegetables: A Step in African Food and Nutrition Security

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Food and nutrition insecurity has been a major challenge in Africa. Farmers need to diversify food production in order to alleviate food and nutrition insecurity. With climate change at hand, indigenous vegetables can provide prospects to diversify production systems and improve food, nutrition and income security in many countries. Regardless of their potential, the extent of consumption and diversity of indigenous vegetables in lessening food, nutrition and economic insecurity are not fully exploited in Tanzania. Estimation of consumption intensity of these vegetables is important to understand how their utilisation can be enhanced at the household level.

The study evaluated consumption intensity and production constraints of indigenous vegetables. The study was carried out on 600 farm households from four villages in Dodoma and Morogoro, Tanzania. A multi-stage sampling procedure was used to select districts, villages and households. Districts were selected purposively based on their different agro-ecological characteristics and data was collected using a structured questionnaire.

The mean consumption of indigenous vegetables was high in 74 % of households, but the quantities were below 80 % the recommended daily intake (RDI) in 72–96 % of households. The mean intakes of vegetables were significantly ( $p < 0.001$ ) different among the two agro ecological zones. Age of household head, household size and distance to a water source influenced consumption intensity of indigenous vegetables. Identified production constraints were lack of knowledge on the vegetables for example; production practices, cooking methods, utilisation and preservation methods; lack of seeds, low yields and competition with some exotic.

The diets of rural community were somehow deficient in terms of different vegetables and amount consumed thus contributing to high prevalence of undernutrition and micronutrient malnutrition. Therefore, strategies that could promote consumption intensity of indigenous vegetables such as health and nutrition education and involving young and male decision makers, extension services and production of these vegetables in home gardens should be employed.

**Keywords:** Food and nutrition security, indigenous vegetables, undernutrition

## Can African Indigenous Vegetables Contribute to Nutrition Security in Kenya?

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Kenya is classified as a food deficit country, close to one of each three Kenyans (14.5 million) suffers from chronic food insecurity and poor nutrition. In addition, about 30 percent of the children country wide are stunted, 13 percent moderately wasted, while 7 percent are moderately underweight. Approximately 20 percent of the population does not attain the minimum dietary requirements to sustain a healthy and productive life according to the National Bureau of Statistics. African indigenous vegetables (AIVs) contain a lot of beneficial micro-nutrients, which are critical for achieving nutrition security. The study seeks to assess the household preferences regarding vegetable consumption. A mixed method approach was used to analyse a panel dataset that covered 706 households in four counties in Kenya. The data was collected between 2014 and 2016.

The results show that, the consumption of AIVs is not widely acknowledged or documented. This is because the vegetables are usually consumed as an accompaniment. Households purchased an estimated 10 percent of their vegetable requirements and spent 16 times more on exotic vegetable when compared to how much they spend on AIVs. In seasons when households did not have enough food they spent 19 times more money on exotic vegetables when compared to AIVs. In cases where households had enough food they spent 9 time more money on exotic vegetables. This is an indicator that exotic vegetables were the preferred vegetables for most households that purchased vegetables. For the households that produced AIVs their consumption was positively correlated with their household income, household size, the amount of land under AIVs and their food security status. The study proposes the following; First, concerted efforts are needed to increase the availability and consistent supply of AIV products in the market. Secondly, innovations need to be upscaled to show case the nutritional benefits of AIVs for the different stages of growth, to support the life cycle approach in the management of nutrition security.

**Keywords:** African indigenous vegetable, food security, nutrition security

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## Investigation of Physiochemical Characteristics of Wild Fruits and Berries from the Walnut-Fruit Forests of Southern Kyrgyzstan

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The physicochemical properties and nutritional value of wild fruits and berries commonly growing in the walnut-fruit forests of southern Kyrgyzstan were determined to evaluate the capacity for use in the food processing industry. The investigated species were selected based on their reported nutritional aspects and medical properties and included apple (*Malus sieversii* var. *kirgizorum*), barberry (*Berberis oblonga*), cherry-plum (*Prunus divaricata* black, red, yellow), dog-rose (*Rosa canina*), hawthorn (*Crataegus songorica*), pear (*Pyrus korshinskyi*), and sea buckthorn (*Hippophae rhamnoides*). The fruits were collected from the natural walnut-fruit forests in the communities of Arslanbob (N 41°22'8.33", E 72°3'45.974", Altitude: 1300 m) and Kyzyl-Unkur (N 41°18'20.903", E 72°57'48.209", Altitude: 1466 m) in September 2017. The nutritional value of the samples was determined in terms of moisture, carbohydrates, alimentary fibre, vitamin, ash, titratable acidity, total polyphenols (TPC), total antioxidants, and total anthocyanins. The results of the analysis showed that the investigated fruits and berries have a moisture content ranging between 59.52 % (*Berberis oblonga*) and 85.14 % (*Malus sieversii* var. *kirghisorum*), carbohydrates ranging from 0.50 % (*Hippophae rhamnoides*) to 10.29 % (*Pyrus korshinskyi*), alimentary fibre ranging from 0.73 % (*Prunus divaricata* yellow) to 13.19 % (*Berberis oblonga*), vitamin ranging between 7.39 mg/100 g (*Prunus divaricata* yellow) and 492.35 mg/100 g (*Berberis oblonga*), and ash content ranging between 0.30 % (*Malus siversii* var. *kirghisorum*) and 2.70 % (*Rosa canina*, *Berberis oblonga*). Among all the samples analysed, the *Berberis oblonga* revealed the highest TPC at 2578 mg gallic acid equivalents/L followed by *Rosa canina* (2144 mg GAE/L). Between the samples, the lowest TPC value was found for *Prunus divaricata* yellow (611 mg GAE/L). All the studied fruits and berries can serve as a good source of bioactive compounds in the human diet. From the view of the phenolic content and antioxidant activity, barberry can be regarded as a good raw material for the production of healthy and/or functional foods.

The study was conducted within the SUSWALFOOD project.

**Keywords:** Berries, fruits, Kyrgyzstan, physio-chemical properties, total anthocyanins, total antioxidants, total polyphenols, walnut-fruit forest

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## **Insects for Food! Factors Influencing Consumer Acceptance and Quantity Consumed of Edible Winged Termites**

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Developing countries are faced with increased population growth and urbanisation resulting in high demand for food, especially animal based protein. The dilemma is how to meet the rising demand for animal based protein in the face of climate change. Utilisation of edible insects as food offers a possible sustainable solution to meet the rising protein demand besides its high nutritive value. Edible winged termites (EWT) consumption and commercialisation is gaining popularity among consumers in western Kenya. Despite EWT having economic, nutritional and environmental benefits, information on factors influencing its acceptance and demand is scanty among rural and urban consumers. The aim of this study was to assess consumers' socio-economic, institutional and EWT characteristics influencing its acceptance and quantity consumed. Multistage sampling procedure was used to sample 384 rural and urban consumers in Western Kenya. Data was collected through face to face interviews using pre-tested semi-structured questionnaire by well-trained enumerators. Data was analysed using factor analysis and Craggit model. Consumer's perception of EWT was categorised into three: EWT attributes, convenience and culture. Acceptance and demand of EWT was influenced by gender, education, higher number of children below 5 years, income, household being a native of western Kenya and EWT attributes among rural and urban consumer. We recommend more education on use of edible insects as food, with much emphasis on its benefits and desirable attributes. This can be done through established cultural centres and 'food clinics' to create awareness among consumers to enhance the commercialisation of EWT value chain. Further, there is need to in cooperate entomophagy in formal education curricula to promote the transfer of knowledge to future generations.

**Keywords:** Consumer acceptance, craggit model, demand, edible winged termites, factor analysis

## Analysis of Nutritional Composition of Edible Insects to Enhance Nutritional Security in Sub-Saharan Africa (EntoNutri)

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While insects are a relatively new food item in western societies, they form an integral part of many Asian, Latin American and African cuisines. In Kenya and Uganda for example, edible insects already make up 5–10% of the total protein intake and trade in edible insects is a major source of income, especially in rural areas. Therefore edible insects have the potential to play a vital role for food and nutrition security in both countries. However there is little knowledge on sustainable rearing and harvesting techniques. Furthermore, insects and their feed can be contaminated by heavy metals or insecticides. EntoNutri is a multinational, multidisciplinary project whose goal is to improve food and nutrition security as well as the economic wellbeing of rural and urban communities, particularly smallholders, women and youth through the development, dissemination and promotion of environmentally sustainable insect-based technologies to enhance productivity and consumption of insects as food. The Food Security Center (FSC) of the University of Hohenheim is also a partner in this project. The FSC's specific project goal is to establish the nutritional profile of target insect species along the process chain, with special focus on the micronutrient composition, as the possible contribution of insects to the micronutrient intake of their consumers is not well known. Therefore long horned grasshoppers (*Ruspolia differens*) from Uganda, as well as crickets (*Gryllus bimaculatus*) and several kinds of caterpillars (*Imbrasia zambesina*, *Cirina forda*) from Kenya, were collected in the respective country. If available, samples were collected fresh and in various kinds of processing e.g. boiled or fried. If the sample was only available in one of the respective forms only the available form was sampled. The samples will be analysed for their content of riboflavin, niacin, vitamin A and carotenoids via HPLC methods as well as their content of dietary minerals (iron, zinc, etc.) analysed by mass spectrometry, to evaluate if edible insects can also be a viable source of micronutrients. To ensure that insect and insect products are safe for human consumption, levels of heavy metal contaminants will be also analysed by mass spectrometry.

**Keywords:** Food analysis, food security, insects, nutrition security



## Can a Smallholder Farm Sufficiently Feed the Family? A Case Study from Kapchorwa District, Uganda

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Despite Uganda's high agricultural potential, the hunger situation is classified as "serious". Access to food is limited for many people and subsistence farming often represents the main source of food. Recent research has been working on finding a link between increased agrobiodiversity and household nutrition. However, no research has been done focussing on the amount of nutrients produced on farms and to what extent the nutrients could potentially cover the households' requirements. Therefore, the objectives of this study were to (i) investigate whether smallholder farmers could produce enough nutrients to cover the households' requirements and (ii) identify whether missing nutrients are specific to certain households or insufficient in the whole region. The results will be used for linked agriculture – nutrition interventions.

The data was collected during the long rainy season (March-August 2016) and covered the produced food diversity (plant and animal products) and yields of 58 smallholder farmers' households in Kapchorwa, Uganda. Energy, carbohydrates, fat, protein, iron, zinc, vitamin A, vitamin C, calcium, potassium, magnesium, copper, folate, vitamin B12 and selenium content were calculated for all produced yields of each household using food composition databases. Dietary requirements of each household were calculated using recommended daily allowances. Finally, the average daily amount of nutrients produced per household was calculated and compared to the households' requirements respectively.

Not a single household produced enough nutrients to meet its members' requirements, nor was there a nutrient that every household could produce sufficiently. Particularly vitamin B12, vitamin A, calcium, and iron were insufficiently produced. While only one or two households could supply enough vitamin B12 and calcium, six households could potentially meet their vitamin A requirements. The main source of nutrients came from plants, as animal source foods were very rarely consumed. Hence, the bioavailability of some nutrients was likely to be low. A higher diversity of cultivated crops was associated with a higher coverage of some nutrients. Identified entry points for interventions would therefore include adding a higher diversity of micronutrient-rich plant source foods to the food basket through subsistence farming, as well as encouraging an increased consumption of animal source foods.

**Keywords:** Agriculture, biodiversity, food composition, nutrition

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## Community Restaurants as a Policy Instrument Against Hunger: The Case of Toledo (Brazil)

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Community restaurants is a programme in Brazil, which aims to get close the producers' and consumers' sides of the food chain. On one hand, it promotes products produced by family farms, considering the singularities of the region. On the other hand, it subsidizes consumer prices for locally produced nutritious food, especially in poor neighbourhoods. The community restaurants in these areas mainly operate during lunchtime, which is the most important meal in Brazil. A nutritionist helps to improve the nutritional quality of diets through "*mistura*" (mixture) of locally available products such as rice, beans, meat and salad. This article aims to analyse how public policies have contributed to the success of the Community Restaurant Program. It also aims to describe qualitatively and quantitatively all sectors that interacted directly or indirectly with this program, using Toledo (state of Paraná) as a study case. For these purposes, we employed the Delphi methodology and the prospective analysis using the MICMAC software. Results indicate that, family farmers were the most important stakeholder group with a considerable impact on the performance of the community restaurants. As such, despite Paraná's national importance for the poultry, swine and soybean production on a large scale, its very dynamic and diversified family farming sector was a main ingredient of success of this program. This study also identifies the influence of other public policies at the municipal, state and federal levels on the community restaurants in Toledo. It concludes that while public policy support was the key factor for the successful establishment of the program, ensuring the long-term social impact and financial viability of the programme will be important for its continued operation.

**Keywords:** Brazil, community restaurants, family farming, public policies, Toledo

## Potential of Asian Herbaceous Plants as Source of Micronutrients

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Deficiency of micronutrients is a major problem worldwide leading to increasing rates of several illnesses by reducing immune and non-immune defenses. Especially diets of poor people are based on few crops rich in macronutrients, whereas the nutritional value of other plants is not fully exploited.

Previous studies at Humboldt University of Berlin already dealt with various herbaceous, nutraceutical Asian plants like *Oenanthe javanica*, *Ipomoea aquatica*, *Crysanthemum coronarium*, *Elsholtzia ciliata* and *Ocimum basilicum*. For this research project *Perilla frutescens* and *Persicaria odorata* have been selected due to their high content of antioxidants and their easy cultivation. Both plants are already used as basic ingredients and food additives in Asian cuisine and are known for their health improving and medicinal benefits. Aim of our research was to analyse and to evaluate the nutritional value of its contained micronutrients. Cultivated in a greenhouse in Berlin, *P. odorata* was harvested five weeks after planting the cuttings and *P. frutescens* ten weeks after sowing. Quantity of marketable fresh matter was about 2.5–4.3 kg m<sup>-2</sup> for *P. odorata* and about 4 kg m<sup>-2</sup> for *P. frutescens*. Regarding micronutrients *P. odorata* had remarkable high contents of ascorbic acid (around 180 mg/100 g) and flavonoids (around 500 mg/100 g). Therefore, 55 g of *P. odorata* would be sufficient to comply dietary intake recommendation for ascorbic acid by D-A-C-H organisation (Union of German, Austrian and Swiss food associations). *P. frutescens* was particularly rich in polyphenols (880 mg/100 g) and anthocyanins (200 mg/100 g FW).

Analyses of mineral contents proved potassium as major constituent (40 mg g<sup>-1</sup> DW for *P. odorata* and 30 mg g<sup>-1</sup> DW for *P. frutescens*) and indicated high amounts of magnesium (7 mg g<sup>-1</sup> DW for *P. odorata* and 5.6 mg g<sup>-1</sup> DW for *P. frutescens*) and iron (0.15 mg g<sup>-1</sup> DW for *P. odorata* and 0.14 mg g<sup>-1</sup> DW for *P. frutescens*). Regarding recommendations of DACH organisation 100 g *P. odorata* could provide around 40 % of recommended magnesium, 34 % of recommended potassium and 25 % of recommended iron intake.

Results demonstrate the potential of *P. odorata* and *P. frutescens* as micronutrient source to satisfy nutritional needs. Both Asian plants are cultivable under protected conditions also in temperate climate zones. Nevertheless, in further researches the influence of different growing conditions and cultivation systems on the yield and micronutrient content should be investigated.

**Keywords:** Minerals, nutraceutical, *Perilla frutescens*, *Persicaria odorata*, vitamins

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## The Water Footprint of Milk in Comparison of Twelve International Farming Systems: An Implication for Global Food Security and Improved Food Nutrition

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A consequence of increasing water scarcity has to impart challenges to global food security. This is due to possible inter-linkage and competition between the water and the food production where food provision is fundamentally guaranteed. Water use (WU) by dairying leads to impacts on ecosystems but milk and other milk products used to support and heighten human life. However, there is lacking awareness of method selection to assess impact and adequate consideration of heterogeneity in production. Therefore, this study compared two methods on 12 regional typical case farms from International Farm Comparison Network that represent three production systems for assessing impacts of consumptive WU and degradative WU of a kg energy corrected milk (ECM) production. The first is the virtual water concept customarily used to consider the volumes of water consumed, and second a life cycle impact assessment (LCA) method is applied for WU which describes the impact contributing to freshwater scarcity. The virtual water content (VWC) results ranged from 787 to 4242 L kg<sup>-1</sup> ECM while the life cycle impact results for WU, referred to the water footprint (WF), ranged from 3 to 1520 L H<sub>2</sub>Oe (water equivalent) per kg ECM at farm gate. As an example, the VWC and the LCA-based WF on the Bangladeshi-two cow farm contained 2579 L kg<sup>-1</sup> ECM and a 24 L H<sub>2</sub>Oe kg<sup>-1</sup> ECM, respectively. The WF results are very heterogeneous due to diverse farming practice geographically, high variation in local water scarcity, and milk production intensity. The results also indicated that minimum input use in relation to consumptive blue water and a pasture-based dairy production system where lower water stress index have a lower impact on freshwater scarcity. VWC as a method of WU is unsuitable to measure the potential to contribute to freshwater scarcity but the LCA-based WF provides a useful dimension to assess impact of consumptive WU contribution to freshwater scarcity. This study suggests that changing production systems in low water stress region and improve their blue WU efficiency, i.e. irrigation services, is to reduce freshwater scarcity for implementing operational plans to sustain food security and food nutrition of people around the

**Keywords:** Food security, life cycle assessment, milk production, water footprint, water scarcity

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## Assessing the Costs and Benefits of Implementing a Quality Based Milk Payment System in Kenya

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Assuring the quality and safety of milk and dairy products has been a persistent problem in the Kenyan dairy sector, caught between limited consumer awareness on quality & safety, processors and traders competing for milk volumes but neglecting quality, poor milk handling practices along the chain, and lack of enforcement of quality & safety regulations. A quality based milk payment system (QBMPS) targeting small-holder dairy farmers was piloted by processor Happy Cow Ltd, aiming to control and improve milk quality and safety along the dairy chain. In order to assess the practicability of a QBMPS in Kenya and to determine pre-conditions for its upscaling, both private and public sector costs & benefits of the system were estimated. Data was collected from key stakeholders targeting costs and benefits of farmers, CBEs (Collection and Bulking Enterprises), the processor and the public.

Our findings show that in cash terms, the farmer is the greatest beneficiary from a well-functioning QBMPS, with a net profit of about 2 KES kg<sup>-1</sup> milk if he produces Grade A milk for the QBMPS. By participating in the QBMPS, farmers also benefit from social inclusion, chain integration and productivity gains. The CBE and processor have a net additional cost (difference between costs and benefits) totalling 2.5 KES kg<sup>-1</sup> milk, mainly driven by the significant initial costs for laboratory equipment, additional staffing and training of farmers. Regarding public health, we estimate an occurrent annual loss of 53,000 healthy life years (disability adjusted life years) in Kenya due to milk related infectious diseases. With a modest commitment of farmers and chain actors, the QBMPS can generate health benefits of about 10 KES kg<sup>-1</sup> milk as avoided health costs from milk related illnesses. These enormous public health benefits could be used as a justification for public and donor investments to support the QBMPS, especially to temporarily compensate the CBEs and processors who currently make a loss from the system. Additionally, we recommend private players to improve their commitment and the government to promote the growth of the formal sector and strictly enforce milk quality standards in order to increase the benefits for farmers and consumers.

**Keywords:** Food safety, milk quality, public health, quality based milk payment

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## Validation of a Food Group Based Nutrition Software to Assess Nutrient Intake in Tanzania

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Analysis of food intake by 24 h recalls or food frequency questionnaires are the common methods to quantify nutrient intake in larger surveys. After data acquisition, data analysis is time consuming and individual results are not provided to the participants. These limitations can be overcome by the nutrition software CIMI, which calculates nutrient intake using food groups automatically and directly after data input. Feedback to the respondent enhances willingness to participate in such surveys and provision of reliable answers. In addition, individual feedback can help to improve nutritional quality. The present study verifies the accuracy of the CIMI programme by comparing the results with the established nutrition software NUTRISURVEY. 24 h dietary recalls of 1013 Tanzanian women from Kilosa and Chamwino districts collected in the TransSEC project (347 women, January to May 2015) and the Scale-N study (666 women, July to August 2016) were analysed by both, single food item based nutrition software NUTRISURVEY (NS) and the food group based software CIMI. Macro- and micronutrient intake calculation between NS and CIMI were compared using SPSS 24. Differences in nutrient intake between CIMI and NS were marginal: out of the 14 analysed macro- and micronutrients, mean difference  $\pm$  standard deviation was for energy +65kcal  $\pm$  283, protein -1.4g  $\pm$  15.5, retinol equivalents -170  $\mu$ g  $\pm$  715, vitamin B1 +0.15 mg  $\pm$  0.33, iron +1.5 mg  $\pm$  10.7, and zinc -1.2 mg  $\pm$  2.6. Nutrients with a very high accuracy (difference expressed as % of NS result:  $\pm$ 0<5%) were energy, protein, carbohydrates, vitamin B2 and B6. Those with a good accuracy ( $\pm$ 5–15%) were vitamin B1 and C, iron and zinc. Moderate accuracy ( $\pm$ 15–30%) showed retinol equivalents, vitamin B12, folic acid and calcium. Fat was the only nutrient which was not calculated adequately by CIMI. CIMI is a valid and timesaving instrument to measure nutrient intake in Tanzania. Adjustment of food groups by the respondent will be implemented in a soon available CIMI-app, and will therefore lead to even more accurate results in the evaluation of nutrient intake.

**Keywords:** 24h dietary recall, dietary intake, hidden hunger, nutrients

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# Nutrition, food safety and -security

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DANIEL AYALEW MEKONNEN, AAFKE NIJHUIS, LAURA TRIJSBURG, ELISE TALSMA, TOMAS MORLEY, VINCENT LINDERHOF, THOM ACHTERBOSCH, INGE D. BROUWER:  
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## Dietary Gaps in Ethiopia and Nigeria

DANIEL AYALEW MEKONNEN<sup>1</sup>, AAFKE NIJHUIS<sup>1</sup>, LAURA TRIJSBURG<sup>2</sup>, ELISE TALSMAN<sup>2</sup>, TOMAS MORLEY<sup>1</sup>, VINCENT LINDERHOF<sup>1</sup>, THOM ACHTERBOSCH<sup>1</sup>, INGE D. BROUWER<sup>2</sup>

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Co-existence of undernutrition along with micronutrient deficiencies, overweight and obesity and non-communicable diseases is a growing challenge in low and middle income countries. A food systems approach will help to pinpoint the problem areas in the food system and could aid in the design of interventions. In this context, we investigate dietary gaps - difference between intake and the target amounts - on the level of food group, dietary diversity, and nutrient intake. We use the latest rounds of Living Standard Measurement Surveys (2015/16 LSMS-ISA) from Ethiopia and Nigeria. We estimate nutrient and dietary gaps for the individual from household data, in terms of adult female equivalent (AFE) which proxies intrahousehold distribution of food. Dietary gaps are assessed based on food groups which make up “healthy diets,” according to the Dietary Approaches to Stop Hypertension (DASH) and Global Burden of Disease (GBD) dietary recommendations. We choose the DASH and GBD because available evidence shows these dietary recommendations are designed to prevent diet-related chronic diseases and are globally applicable and not country specific. We conduct nutrient intake gap analysis using the Estimated Average Requirements (EARs) based on European Food Safety Authority (EFSA) recommendations. Further, we assess the dietary diversity using the Household Dietary Diversity Score (HDDS), a composite measure and proxies for household’s average food access. Preliminary HDDS results show that: people in the higher income quintile had access to more diverse food in both Ethiopia and Nigeria; and, consumption of fruits, meat, and eggs show the highest difference between people in the top and bottom income quintiles, in comparison to other food groups in the HDDS. Data analysis is ongoing, but when completed we will map dietary profiles for each country by different settings, including location of residence (rural-urban), sub-national and national level, and across income quintiles. We will present shares of households who deviate from the recommended dietary thresholds (i.e. both excesses and shortfalls), and the magnitude by which they are off the recommended intake. Further, the adequacy of nutrient intake will be shown.

**Keywords:** Caloric intake, dietary diversity, dietary gap, Ethiopia, micronutrients, Nigeria

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## Relationship between Dietary and Serum Aflatoxin Levels and Nutritional Status of Children of 6–24 Months

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In Chipata and Monze districts of Zambia, most of the mothers/caregivers use cereal-based complementary foods that are prone to aflatoxin contamination. This study aimed at evaluating aflatoxin exposure in children 6–24 months and its effect on their nutritional status. The study covered 400 mothers having children 6–24 months. The nutritional status of children was assessed by measuring weight and height using standard procedures and height-for-age, weight-for-age and weight-for-height indices were determined using WHO-Anthro software 2006. The children serum samples were analysed for aflatoxin B1-lysine (AFB-Lys) using high performance liquid chromatography–electrospray tandem quadrupole mass spectrometry (HPLC-ESI-MS/MS), and normalised to serum albumin (Alb+) determined by use of a colourimetric assay on a clinical analyser. Binary logistic regression analysis was used to find the factors affecting child stunting level. A total of 19.82 % of the children were stunted, 9.78 % underweight and 2.85 % were wasted. The AFB-Lys for children from Chipata children ranged from 0.03 to 6.4 ng mL<sup>-1</sup> and that of Monze ranged from 0.04 to 13.0 ng mL<sup>-1</sup>. The mean level of AFB-Lys of children from Monze was significantly ( $p = 0.05$ ) higher than that of Chipata. The Chipata and Monze children showed mean level of Alb+ of 4.14±0.36 g dL<sup>-1</sup> and 4.16±0.34 g dL<sup>-1</sup> respectively. The AFB-Lys (Normalised to Albumin) level was found to range from 0.78 to 202 pg mg<sup>-1</sup> for Chipata children and that of Monze children ranged from 0.92 to 315 pg mg<sup>-1</sup>. Child sickness, child age, exposure to aflatoxin in foods and AFB-Lys (normalized to albumin) level were found to be significantly ( $p < 0.05$ ) associated with child stunting except the child age that was not significant at  $p = 0.05$ . The increase in the exposure of aflatoxin through consumption of contaminated complementary foods leads to 1.771 times likelihood of the child being stunted (odd ratio = 1.999, P-value = 0.0488). However, the children with increase in the blood serum aflatoxin B1 lysine adduct are likelihood to be stunted (odd ratio = 1.301, P-value = 0.0146). These results have shown that dietary exposure to aflatoxin could lead to increase in the serum aflatoxin level and both are associated with stunting.

**Keywords:** Aflatoxin, children, complementary foods, dietary exposure, nutritional status

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## No Suitable Diet Quality Index for Food System Research in Low and Middle Income Countries?

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Food systems research increasingly focuses on improving diet quality in low and middle income countries (LMIC), where the risks for negative health consequences of both under- and over-nutrition, are rapidly increasing. This focus goes along with the need for sound metrics to assess diet quality. This systematic literature review aimed to describe existing diet quality indices for general populations and highlights recommendations for developing such indices for food system research in LMIC. Three electronic databases, Scopus, CAB-abstracts and MEDLINE, were searched for papers published between January 2008 and December 2017. Eighty-one indices were identified, over two third were based on national dietary guidelines from high-income countries. Of the three key diet quality dimensions, ‘diversity’ was included in all 18 indices developed for LMIC, ‘moderation’ was captured by most, and ‘nutrient adequacy’ was included four times. It is needed to develop indices that include all dimensions, foods and/or food groups rather than nutrients, a minimum, maximum or optimal range cut-off for the individual components in the score and express the intake of healthy and unhealthy components separately. Country specific food based dietary guidelines (FBDG) are tailored to a countries’ specific disease profile and food habits and are therefore important indicators for within country comparison, whereas a globally applicable diet quality index would allow for comparing the diet quality of various countries, which is often an important prerequisite of such a metric in food system research. There is an urgent need for the development of both country specific FBDG based indices in LMIC and a global diet quality index. Any diet quality index will have to be extensively evaluated before widely applied in research.

**Keywords:** Diet quality, dietary index, food systems, low and middle income countries

## **Ebola Foresight: The Role of Livestock and Wildlife in the Biology of Ebolaviruses**

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The Ebola virus (EBOV) outbreak in West Africa in 2013–2016 severely affected Sierra Leone, Guinea, and Liberia, which have very weak health systems and limited human and infrastructural resources. Described as the largest ebolavirus outbreak ever recorded, more than 28,000 people were affected with more than 11,000 deaths. The need for a proactive response to manage future outbreaks has led to the conception of the “Ebola Foresight” project, funded by the German Federal Ministry of Food and Agriculture. The project is implemented by a consortium including the Friedrich-Loeffler-Institut, the Sierra Leone Agricultural Research Institute, Njala University, and the Institut Pasteur de Guinée. It aims to build laboratory capacities in Sierra Leone and Guinea in order to ensure preparedness and a rapid response to potential future outbreaks of ebolaviruses or other emerging diseases. Further, a second focus of the project is to investigate the role of wildlife and livestock, in particular pigs, in the biology of ebolaviruses. Though serological and molecular evidence points towards certain fruit bat species as the natural reservoir host for EBOV, experimental studies indicated that pigs can also be infected with EBOV. Thus, the potential role of pigs in the maintenance and transmission of EBOV is yet to be understood. In December 2016, 400 pig serum samples were collected in three districts in Sierra Leone for serological investigation. Surveillance targeted communities that were heavily hit by the EBOV epidemic with reported close interaction between wildlife population and domestic pigs. The pig sera were initially tested for ebolavirus antibodies by using an in-house ELISA, and positive sera were tested for confirmation by immunoblot based on several ebolavirus nucleoproteins and virus-like particles (VLPs). Those sera were also analysed in a serum neutralisation test based on transcription and replication competent VLPs under biosafety level (BSL) 2 conditions as well as against EBOV under BSL4 conditions. The results suggest the occurrence of ebolaviruses in swine in Sierra Leone that are antigenically related but not identical to EBOV, and carry an unknown pathogenic and/or zoonotic potential.

**Keywords:** Capacity building, ebolaviruses, pigs, serology, West Africa

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## **The Effect of Individual Preferences on Food and Nutrition Security. Evidence How Risk Preference, Future Discounting and Altruism Affect Food Consumption of Individuals and Households**

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The probability of a sufficient calorie intake and a diverse diet is related to various social, economic and political factors. Often neglected, individual preferences and motivation often form nutrition choices as well. Particularly core concepts of behavioural economics – altruism, risk and time preferences – affect consumption choices of individuals, and of dependent household members. Therefore, this study explores the linkages between behavioural preferences and food and nutrition security utilising a household-level survey and games for preference elicitation. The study adds to the literature theoretically and empirically by assessing the influence of core concepts of behavioural economics on food and nutrition security.

We extend the theoretical literature by adding a stochastic component for future periods to an expected utility optimisation approach. Expectations of a normally distributed future outcomes vary depending on individual risk considerations and discount rates. Altruism and reciprocity levels additionally determine food sharing within households in the current period.

The household survey is carried out in rural areas of India, in regions with severe malnutrition rates and high poverty rates. 954 households are interviewed with each having at least one child below 2 years of age. The households are selected using a stratified randomised sampling technique from 85 villages. Food and nutrition security indicators are obtained (e.g. FIES, MDDW, MAD, anthropometric measurements). Hypothetical games are used in a mix of qualitative and quantitative questions for preference assessment. These elicit risk preference, time preference and altruism of the household heads and the spouses.

Controlling for individual, household and village covariates, we find that female individuals that are 1 SD more risk affine than average have a 30 % better dietary diversity score. We further find that male household heads with a 1 SD higher altruism level than average improve the dietary diversity of their female spouses by around 5 %. Risk affinity can also increase the food access of households by 13 % (measured as household dietary diversity score). Effects on anthropometric measurements indicate that higher risk affinity and a lower discount rate positively affect the height of women, indicating a long-term effect.

**Keywords:** Behavioural economics, food and nutrition security, individual preferences

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## Biofortified Food Choice in Zambia. Farmers' Views on Vitamin A Maize in two Rural Communities

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Vitamin A deficiency is a global public health challenge causing preventable blindness in children and pregnant women. It leads to impaired growth and increased risk of disease and death from common childhood infections such as diarrheal diseases and measles, and especially heightened risk of maternal mortality among women. In Zambia, 54 percent of children under five are reported to be vitamin A deficient and 14 percent of pregnant women. The IFPRI-led Agriculture for Nutrition and Health (A4NH) programme HarvestPlus supports the breeding, testing, and release of vitamin A maize varieties in the country. Three varieties were officially released in 2012, and to date the HarvestPlus programme has spread to five provinces and it was estimated that 100,000 households would grow Vitamin A maize by 2016. Following five years of delivery efforts, a gender sensitive monitoring study was jointly conducted in September 2017 by HarvestPlus and the Swedish University of Agricultural Sciences to assess progression and understand farmers' perceptions about these varieties and the effects on their wellbeing. In this paper we specifically discuss rural farmers' decisions related to biofortified food choice, including socio-cultural, economic, and agro-ecological factors. The data stem from eight focus group discussions with women and men farmers and 22 individual interviews with farmers and key informants in two villages located in Chirundu and Chipata districts. The findings of this paper improve our understanding of factors necessary to consider in order to scale-up the consumption of biofortified foods in central and eastern Zambia. The paper also shows the value of a social relations approach, as advocated by feminist scholars, when performing this type of implementation assessment studies. As such, it can inform the design of future agricultural interventions.

**Keywords:** Biofortified crops, food choice, gender, social relations approach, vitamin A maize, Zambia

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## Feed Safety and its Impact on Food Safety through the Concept of One Health

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Animal feed is essential in the global food industry for sustainable production of safe food from animals. Feed safety directly affects food safety and human health, through the health and well-being of animals. It serves as a component of access to trade and competitiveness, income generation and foreign exchange earnings as well as economic development and sustainability along the livestock value chain. Feed is an integral part of the food chain and feed safety. Therefore attention must also be on feed production like we have in food production, under the concept of one health.

Ensuring food safety remains a significant challenge in both developing and developed countries because it is an important public health problem that relates to human health and economic development. Various food related diseases originating from animal feeding include bovine spongiform encephalopathy (BSE) and foot-and-mouth disease (FMD). Related problems include the development of resistance in humans to antimicrobials. Salmonellosis with very high chances of cross infection from infected animals. Globally, about 93 million cases of non-typhoidal *Salmonella* and 155,000 deaths have been reported. Annual antimicrobial resistance cases of 4,375,000; 4,125,000; 375,000, and 315,000, in Asia, Africa, Europe, and USA, respectively have been reported.

Presently, the different challenges confronting the industry will require global solutions, including the spread of infectious diseases that emerge or re-emerge through cross contamination between animals, humans, and the ecosystems. Other challenges are lack of know-how to regulate operators to ensure feed safety along the livestock value chain, absence of structure control systems, introduction of unconventional feed ingredients into the production chain like insect meal, by-products of food processing and further foods. Thus, the possibility of additional safety risks in the use of these feed sources for animals exist.

In Nigeria, the Nigerian Institute of Animal Science (NIAS), has regulations for the feed milling industry in Nigeria in line with Codex Alimentarius and other international standards, through the concept of 'One Health' with the sole objective to lower the global impact of diseases of animal origin and zoonoses.

**Keywords:** Feed and food safety, food animals, One Health

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## Edible Mushrooms: Novel Food Fortification Approach Towards Food Security

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Physicochemical attributes of mushrooms (*Agaricus bisporus* & *Pleurotus ostreatus*) and their blends with maize flour, as well as the colour and sensory acceptability of the fortified maize-mushroom porridge were investigated using standard analytical techniques and Pearson's correlations. The maize flour was replaced with mushroom flours at different levels; a control sample (0 %), 10 %, 20 %, 30 %, 40 % and 50 % of mushroom flour. Increasing mushroom content resulted in increasing of protein, ash, fibre, zinc and iron content in both composite flours and fortified maize-mushroom porridges. Furthermore, the fortified maize-mushroom porridges *in vitro*-protein digestibility increased with increasing the mushrooms content. Adding *P. ostreatus* flour resulted in increasing of the pH and decreasing of the total titratable acidity (TTA). On the other hand, increasing the *A. bisporus* flour content resulted in decreasing of the pH and increasing of the TTA. A strong significant ( $p < 0.05$ ) linear correlation (-0.73) was observed between the *in vitro*-protein digestibility and the viscosity in maize-mushroom porridges. Besides, increasing mushroom content resulted in decreasing of the fat, carbohydrates and energy content in both composite flours and fortified maize-mushroom porridges. The fortified maize-mushrooms viscosity also decreased with increasing mushroom flour content. In addition, a positive significant linear effect ( $p < 0.05$ ) in the composite flours on foaming capacity, foam stability, fat absorption capacity, water retention capacity, water absorption capacity, solubility index and swelling capacity was observed, while a negative linear effect on compact density, bulk density and syneresis was found. However, the gelation capacity, emulsifying activity and emulsions stability in the blend were not affected with adding *P. ostreatus*, while a slight decrease was observed with adding *A. bisporus*. Increasing mushroom flours content resulted in decreasing of the lightness ( $L^*$ ) value and increasing of redness ( $a^*$ ) and yellowness ( $b^*$ ) in both composite flours and porridge. Based on the colour as well as the consumer acceptability, porridge and maize flour supplemented with 10 % and 20 % *P. ostreatus* flours were found to be the best. The information provided in this study increases the attractiveness of the mushroom flours as a novel food fortification due to their nutritional attributes that are associated with numerous health-promoting benefits.

**Keywords:** Consumer acceptability, fortified porridge, maize flour, physicochemical properties

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## Decision Analysis Tools Reveal Benefits of Fruit Trees for Enhanced Nutrition Security in Kenya

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Decision analysis tools can help to utilise available data and expert knowledge rather than requiring hard data from costly long-term fieldwork and experiments. They allow for the incorporation of disparate data sources and what might be considered ‘imprecise’ inputs to create a representation of the current understanding of cause and effect relationships within the target system. Such tools were applied to provide evidence-based support for policy decisions regarding planting varieties of mango (*Mangifera indica* L.) and avocado (*Persea americana* Mill.) trees in Kenya. A group of twenty experts, including representatives of government and non-government organisations, agricultural technicians and practitioners, academics and analysts, collaboratively modeled the potential livelihood impacts of planting fruit trees on smallholder farms in Kenya. The critical determinants of the effectiveness of these trees for household nutrition were established. Estimations on variables and relationships were generated from expert knowledge and available data. These were used to programme four comprehensive Bayesian Network models of around 60 variables each to show the difference in the annual dietary gap in terms of estimated average requirement of energy, iron, provitamin A and zinc per person in smallholder households. Model results indicate that planting fruit trees can benefit the nutritional status of households, decreasing risks of hunger and micronutrient deficiency. The results show substantial differences in potential nutrition outcomes between planting vs. not planting fruit trees. Overall the results suggest that planting fruit trees may result in a lower per person dietary gap for provitamin A (median 58,871 vs. 204,060 mcg retinol activity equivalents/yr), iron (-332 vs. 759 mg yr<sup>-1</sup>), zinc (1,424 vs. 2,299 mg yr<sup>-1</sup>), and energy (341,070 vs. 364,270 kcal yr<sup>-1</sup>). Results can be used to inform policies related to fruit tree planting and to plan for potential outcomes of development actions in Kenya.

**Keywords:** Avocado, bayesian network, energy, iron, mango, provitamin A, smallholder farmer

## Improving Milk Quality in Smallholder Dairy Systems: Towards Realising Food Safety and Food Security in Kenya

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Smallholder dairy value chains provide high quality protein for consumers, and income and employment for farmers and dairy value chain actors in Kenya. Milk quality in the informal value chain, the primary market channel in Kenya is variable, often does not meet standards, undermines food security and food safety, and constitutes a constraint to long-term sustainability of the sector. An improvement in milk quality would enable Kenya to move towards realising sustainable food security as envisioned by the United Nations sustainable development goal 2. To achieve improved milk quality, there is need to focus on prevention of hazards (chemical, physical and microbial contaminants) notably, through implementation of existing but unenforced quality assurance systems in the value chain.

This study was carried out in Nakuru, Nyandarua and Laikipia counties in Kenya using a mixed methods approach. A spatial framework for market quality guided the study and considered urban and peri-urban locations (PUL), mid-rural locations (MRL) and extreme rural locations (ERL). A questionnaire was administered to 652 smallholder farmers to elicit information on farm practices and knowledge relating to milk quality. 432 milk samples were collected in the formal and informal value chains. Analyses for composition, microbial contamination were undertaken. Observations were made across the value chains. Finally, key informant interviews were held to triangulate information.

Findings revealed high microbial contamination in all three counties (*E. coli* 35.2 %, *Pseudomonas spp.* 53.4, *Staphylococcus spp.* 2.5 % and 2.3 % positive for milk ring test (MRT). Microbial contamination was higher in MRL and PUL than in ERL. Composition revealed mean butterfat 3.58 %, protein 3.53 % and solid not-fat 9.190 %. Protein content was below average except in Nyandarua and in MRL when results were analysed according to the spatial framework and counties. Economic incentives encouraging farmers to improve milk quality were lacking. There was low knowledge of milk quality especially of the importance of milk composition across all counties. Institutional capacity (under-staffing and lack of resources) constrained the implementation and enforcement of milk quality control systems. Observations revealed the use of non-food grade plastic containers and poor handling of milk by actors across the value chain.

**Keywords:** Dairy value chains, food safety, food security, milk quality, SDGs

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# From Farm to Fork. How Production Diversity Determines Nutrition Security of Smallholder Farmers in Rural India

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There are various pathways through which agricultural production can affect dietary intake of individuals and households. On-farm production diversity of smallholder farmers can improve the nutrition security of the household. We understand on-farm production diversity as any production of food items at the household level (i.e. field crops, garden crops, livestock). The objective is to determine the significance and relevance of this relationship by considering the different degrees of separability between both the commercial and consumptive production of food. A household-level survey covering socioeconomic, agricultural and nutritional data was conducted in three regions of India from January to June 2017 including 1324 households in 119 villages. We use an instrument variable identification strategy to estimate the effect of production diversity on dietary diversity. Various regression specifications (OLS, Poisson, Probit, IV / non-IV) were used for robustness checks. Considering agroecological zones represented by climatic and geographical characteristics, we use average yearly rainfall since 1981 as the excluded instrument. A positive association is estimated ( $\beta$ : 0.417 / 0.016 | IV / non-IV). We extend the framework by interacting production with access to markets and we find that households that are more integrated into regional markets, improve dietary diversity on average by 0.5 food groups. The increase is significant only for a few food groups (dairy products, nuts and vegetable) and primarily, it is the higher income groups that benefit from market integration. In conclusion, production diversity does improve nutrition security, but the positive market effect is stronger for farming households that have a higher income.

**Keywords:** Agricultural production, dietary diversity, India, nutrition-sensitive agriculture

## Assessment of Mineral Content of Different Soil Types Consumed by Pregnant Women in Western Kenya

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Soil consumption (geophagia) has been in practice for more than 2 million years, it has been reported in different cultures in different parts of the world. This practice has been shown to be prevalent in women especially pregnant women. Different soils are chosen because women crave their taste, smell or texture in the mouth and consume the soil to satisfy this craving. Pregnant women in Kenya have been reported to consume soils from different sources, this includes soil from the walls of the houses which is easily available and its taste is preferred. Soft stone is sold in the open air-market or in the high-end market as well as termite soil from termite mounds. Sometimes women collect soil from the ground after a shower, the rich smell of freshly watered soil, can bring on strong desire to crave and ingest it. Samples of soil from houses, termite molds and from the market were collected and analysed for mineral concentrations using inductively coupled plasma optical emission spectrometry (ICP-OES). The different soils were found to have different mineral content ranging from, calcium (0.29-2.69 mg g<sup>-1</sup>), iron (23.61-96.76 mg g<sup>-1</sup>), potassium (8.33-34.74 mg g<sup>-1</sup>), magnesium (0.88-3.65 mg g<sup>-1</sup>), manganese (0.35-3.34 mg g<sup>-1</sup>), sodium (0.66-7.81 mg g<sup>-1</sup>) and silicon (193.36-361.42 mg g<sup>-1</sup>). There were significant differences observed in the mineral concentration in all the samples studied ( $p < 0.05$ ). If a pregnant woman ingest 1 g of the studied soils, they were likely to meet 22 % to 91 % of the woman daily iron requirement. This study indicates the potential importance of ingested soils in supplying significant amounts of several minerals required during pregnancy. Whether this is a safe source for minerals lies the big question.

**Keywords:** Kenya, pica, pregnant women, soils

## **The Impact of Nutrition Training on Mothers' Knowledge and Behaviour in Gangga Island, Indonesia**

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Malnutrition remains a public health concern in Indonesia, particularly in the remote areas where the level of awareness about nutrition is still lacking. Knowledge about good nutrition can lead to a healthier diet for children. According to the General Directorate of Public Health-Indonesia, about 29.6 % of children with stunting condition, and 18.8 % infants aging from 0 to 9 months with malnutrition have been found in Indonesia. Therefore nutrition training may have a good impact on improving the knowledge of mothers, the way they feed their children, and consequently the health of the children by decreasing the malnutrition and stunting condition.

This was a longitudinal study with quantitative descriptive design. The questionnaire was administered to women who have children at risk of malnutrition in Gangga Island. The observation of the mothers' behaviour was done through focus study groups six months after the questionnaire was distributed.

Bivariate analysis showed a significant correlation between nutrition training and increasing the knowledge and behaviour of mothers ( $p < 0.001$ ). An increase of 86.4 % of mothers' knowledge on nutrition and behaviour was shown. Nutrition training has significant impact on the knowledge and behaviour of mothers with children at risk for malnutrition in Gangga Island.

**Keywords:** Knowledge, malnutrition, mothers

## Nutrition Education and Kitchen Garden Intervention Improves Dietary Diversity among 6–59 Months-Old Children in Kenya

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A nutrition education and kitchen garden extension intervention was implemented within the HealthyLAND project in Teso South, Kenya. The objective was to assess change in dietary diversity of children 6–59 months whose mothers participated in nutrition education sessions (NE) or NE plus kitchen garden extension intervention (AGNE). A village list for all non-urban villages from Teso South was collected. The baseline survey targeted 420 children aged 0–59 months and their caregivers selected from 35 randomly selected villages with 12 households targeted per village. Stratified cluster random design was applied on the 35 villages randomised into NE only (n= 11 villages, 132 families), AGNE (12 villages, 142 families) and control (CTRL) (n= 12 villages, 144 families) groups. Community health volunteers (CHVs) undertook eight individual face to face home visits and four group sessions over a period of 4 months for NE. Kitchen garden interventions were carried out by the same CHVs working in collaboration with agriculture extension officers. Chi square and logistic regression analysis was used to measure associations and magnitude of change. Improved dietary diversity was defined as a child aged 6–59 months receiving food from at least four or more food groups out of the WHO child dietary diversity 7-food grouping. This analysis covered 334 respondents among households with children aged 6–59 months at exit survey. There were non-significant differences in baseline minimum dietary diversity by intervention arms; 51.79 % (NE), 51.75 % (AGNE) and 43.52 % (CTRL), ( $p = 0.370$ ). After intervention, there was a significant difference in minimum dietary diversity by intervention arms (n=314); 83.84 % (NE), 84.76 % (AGNE) and 69.09 % (CTRL), ( $p = 0.007$ ). An adjusted logistic regression model showed significant differences in dietary diversity between NE and CTRL (AOR 0.43, 95 % CI 0.22–0.84) but not with AGNE versus NE (AOR 1.07, 95 % CI 0.50–2.28).

Individual nutrition education, and combined nutrition education and kitchen gardens extension interventions had significant effect on child diet quality. Investing in existing agriculture and nutrition staff is a sustainable and feasible approach to improving child nutrition. The study was financially supported by the German Federal Ministry of Food and Agriculture.

**Keywords:** Child dietary diversity, HealthyLAND, kitchen gardens, nutrition education

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## **Sustainable Development: Analyzing Health of Soybean Producers in Brazil through Fertilisers and Pesticides Poisoning**

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This paper aimed to analyse a group of aspects related to the quality of life and, particularly, to the health of conventional and organic soybean producers in the southern region of Brazil. For this survey, 200 farms with similar characteristics were selected – small and medium farms, mostly with family farming workmanship. Through self-reported questionnaires applied to them between November of 2015 and February of 2016, it was possible to access their work conditions and profits related to the two previous harvests, as well as the households' structure. Based on the acute pesticide poisoning, which is a proposed classification tool of the World Health Organisation, a logit estimation model was applied. Comparing the results of typical symptoms of recurrent exposure to fertilisers and pesticides, one concluded that the probability of the conventional soy producer having those symptoms was 20 % higher than the organic producers. Even considering that the average profit of the conventional producers was also higher than the organic ones, and that this group had a broader access to the private health system in Brazil because of their income, this research presented evidences that their physical health is more precarious. The decision to compare producers from the same region, who work with the same crop, standardises our sample and shows that, what sets them apart is the production technology – organic or conventional – and the consequent level of exposure and degree of intoxication. In this aspect, it is an unpublished study. Then, it shows that the apparent environmentally harmonious landscape may not reveal the quality of life of the rural workers, especially with regard to their health.

**Keywords:** Disease, family farming, fertilisers, health, pesticides, soybean



## Food Safety Challenges in Traditional Pork Value Chains and Policy Engagement in Vietnam and Laos

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Food-borne disease (FBD) is a major public health issue in low income countries of South East Asia including Vietnam and Laos. The contamination of popular foods can occur all along the food value chain. Evidence on the burden of FBD is still limited but the risk is expected to be high due to poor food hygiene practices, missing incentives to change them, risky consumption habits and poor enforcement of existing legislation. We will present two case studies conducted since 2015 for Vietnam and Laos. For Vietnam the research included risk assessments (qualitative and quantitative, QMRA) of food safety hazards along the pork value chain (*Salmonella* and chemical) targeting Hung Yen and Nghe An province while for Laos the focus was on parasitic FBD (trichinella) in communities of Savannakhet and Champasak provinces. Nearly half of collected pork market samples (N=217) in Hung Yen and Nghe An (Vietnam) were contaminated with *salmonella* and a QMRA concluded that 1–2 pork consumers from ten are at risk to suffer from *salmonella* related FBD while the chemical risk was low. Results for Savannakhet (Laos) indicate 18 % seropositivity for trichinella antibodies in pigs (N=417), results for Champasak (N=304) are currently analysed. Both case studies were implemented by interdisciplinary research teams. In both studies focus was given on policy engagement (national and lower). In Vietnam this was facilitated through an established taskforce for food safety risk assessment, an alignment with a World Bank funded national food safety assessment initiative and the national food safety working group which included various stakeholders and groups. For Laos a unique cross-sectoral ministerial platform has been established consisting of 6 ministries (agriculture, health, trade, defense, communication and tourism) which advised on community based interventions (e.g. awareness campaigns). Steps towards successful policy and multi-ministry engagement will be presented and discussed.

**Keywords:** Food safety, Laos, pork value chain, Vietnam

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## A Dual Food-to-Food Fortification with *Moringa oleifera* Leaf Powder and *Adansonia digitata* Fruit Pulp

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Malnutrition is one of the most serious problems throughout the world and children are especially vulnerable because of their rapid growth occurring while subject to inadequate dietary patterns. A cost-effective and sustainable alternative is food-to-food fortification by opposition to classical food fortification using chemical ingredients. In such a context, nutrient rich local food resources such as *moringa* leaf powder and baobab fruit pulp are good food fortificant candidates. This research aimed at (i) designing fermented sorghum ogi porridge dual fortified with *moringa* leaf powder and baobab fruit pulp and (ii) assessing iron, calcium and zinc bioaccessibility (IVS) to alleviate micronutrients deficiencies among under five years old children. In this way, fortification rate was defined by integrating traditional practices and literature data related to the amount of fortificant consumed daily by the under five years old children. The *in vitro* solubility (IVS) of the minerals were used as estimate of their digestibility and was assessed by simulating gastro-intestinal digestion. Acceptability test was performed using the facial expression of children and the perception of mothers. The results indicate that fortification increases significantly ( $p < 0.05$ ) calcium content from  $43.6 \pm 1.9$  mg/100 g dry weight to  $3454.5 \pm 86.4$  mg/100 g dry weight, iron content from  $7.3 \pm 0.2$  mg/100 g dry weight to  $88.4 \pm 1.2$  mg/100 g dry weight and zinc content from  $88.2 \pm 3.8$  mg/100 g dry weight to  $202.4 \pm 3.1$  mg/100 g dry weight. In Vitro Solubility (IVS) of zinc significantly increases ( $p < 0.05$ ) after fortification from  $0.5 \pm 0.1$  % to  $2.1 \pm 0.1$  %. The acceptability test indicates that sorghum porridge dual fortified with *moringa* leaf powder and baobab fruit pulp (fortification rate, 17.0 %, dry weight) was the most preferred by children and their mothers. Finally, we suggest that dual food-to-food fortification using *moringa* leaf powder and baobab fruit pulp for porridges be promoted to fight against micronutrients deficiencies especially zinc deficiencies.

**Keywords:** Food to food fortification, *in vitro* digestibility, micronutrients deficiency

## Raising the Burden: Healthy Food and Cooking Energy Scarcity

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Food and nutrition security does not only depend on an adequate quantitative and qualitative availability of especially staples and vegetables. Likewise important is the adequate supply of cooking energy such as fuelwood and charcoal. However, as the process of land degradation is ongoing especially in sub-Saharan Africa - but also in other regions of the global South - forested areas and likewise forest products are diminishing. This has substantial consequences for the 3 billion people globally who depend on so-called traditional bioenergy for cooking but also heating. As the cooking process is essential for nutritious aspects - heat reduces the food matrices and make them more available for the human body -, affected individuals have to develop or apply coping strategies to deal with the challenge of energy scarcity.

We indexed the use of respective coping strategies and quantified their application in the rural and semi-arid region of Dodoma in central Tanzania. As first step, published strategies were identified and clustered via an in-depth literature survey. In sum, 26 strategies were identified in total clustered generally in preventive and acute measures - ranging from introduction of improved cooking stoves to reduction of meals prepared per day. These results were discussed in a series of focus group discussions and expert interviews with villagers in the case study sites of Mzula and Idifu village. Additionally, missing strategies were included as to derive a full picture of strategies applied (23 strategies were applied in the village, two of them not published so far). In total, 39 households were interviewed. In conclusion, affected villagers often only use acute measures that do not tackle the increasing challenge of deforestation. For countermeasures, a long-term strategy needs to be applied by the national and regional governments as well as international donors.

**Keywords:** Bioenergy, energy scarcity, food energy nexus, forest degradation, healthy and nutritious food, woodfuel

## Patulin Exposure among Tunisia Population

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Patulin (PAT) is produced by a wide range of fungal species of the *Penicillium*, *Aspergillus*, *Byssoschlamys*, *Eupenicillium*, and *Paecilomyces* genera of which *Penicillium expansum*, a common contaminant of damaged fruits, is the most important. PAT is the predominant mycotoxin in fruits and fruit-based products. PAT exerts genotoxic and cytotoxic effects in humans. Due to its toxicity and large occurrence, the assessment of populations' exposure to PAT is imperative. Recently, biomarker-driven research aroused as a successful method to assess the exposure in humans to a wide range of mycotoxins such as deoxynivalenol, aflatoxins and ochratoxin A. This was executed through the estimation of their metabolites in biological fluids such as urine and plasma. However, there is a lack of information on the PAT metabolism pathway. To date, PAT's biomarkers remain unknown, and an analytical method to evaluate the PAT exposure through biomarkers has not been developed. The aim of the presented study was to detect reliable PAT biomarkers in both human urine and plasma. An *in vitro* study through PAT incubation with liver cells was executed to detect PAT metabolites. Although PAT is a relatively stable compound, metabolites were detected via the use of state-of-the-art high resolution mass spectrometry, and were described and identified. Then, an *in vivo* study was performed where urine and plasma samples from volunteers (n = 100) were analysed to detect PAT metabolites, and were compared with the obtained *in vitro* results. The detected metabolites in the biological samples can be used as PAT biomarkers in future research. The identification of reliable PAT biomarkers is an important step towards mycotoxin assessment studies.

**Keywords:** Biomarker, exposure, patulin, Tunisia

# Food quality and processing

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## The Effects of Harvesting Conditions and Processing on the Nutritional Profile of *Ruspolia differens*

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Wild seasonal edible insects such as *Ruspolia differens* continue to significantly contribute to the food, nutrition and economic security of many people in Uganda and Africa at large. This research aimed at investigating the effect of season, sourcing geographical area and processing method on the nutrient profile of *R. differens*. On a dry matter basis, proteins (34.2–45.8 %), lipids (42.4–54.3 %) and chitin (8.26–10.79 %) were the most abundant macronutrients while potassium (242.0–673.3 mg/100 g), phosphorus (316.1–626.6 mg/100 g), calcium (34.9–128.0 mg/100 g), magnesium (38.5–69.0 mg/100 g) and iron (33.2–69.0 mg/100 g) were the most abundant micronutrients. Vitamin B12 ranged from 0.22–1.35 µg/100 g. The full amino acid profile was determined, showing a high biological value. The variability in amino acid composition across the different samples (areas, seasons) was low. Oleic acid (C18:1 cis-9) was the most abundant (38.9–42.7 %) fatty acid, followed by palmitic acid (C16:0) (26.6–28.5) and linoleic acid (C18:1 cis-6) (17.6–23.0 %), implying that the *R. differens* fat is highly unsaturated (56.5–65.7 %), similar to chicken and pork but higher than beef. *R. differens* samples from the April season had a significantly higher protein and mineral content than samples from the December season, probably due to the younger growth stage of the grasshoppers. Geographical area also significantly influenced the nutrient content of *R. differens* but not consistently. Boiling and roasting significantly resulted in the loss of lipids, minerals and vitamin B12. Correspondingly, protein content increased. Understanding the nutrient profile of *R. differens* will greatly contribute to defining its key quality attributes and inform development of shelf stable products fit for the formal regulated market. Despite *R. differens*' potential to contribute to combatting the micro and macro nutrient deficiencies especially for protein and iron, the bio-availability of these nutrients need to be investigated. Efforts to rear *R. differens* should be harnessed to ensure its sustainable contribution to food, nutrition and income security.

**Keywords:** Geographical area, nutrient profile, processing, *Ruspolia differens*, season



## Sources of Contamination of Raw Camel Milk with Microorganisms

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Camel milk is the most important nutritional source as well as a remedy for the population in many arid areas. Camel milk is mostly consumed fresh or as a naturally fermented product and hence unpasteurised. However, camel raw milk can be contaminated at any step in milk production and processing and, thus, loses its quality and safety standard. The purpose of the present study was to determine potential sources of microbial contamination of camel raw milk. Bacterial contamination of camel raw milk can occur at four levels, within the udder, after harvest, from the surface of equipment used for milk processing, and during storage and transport. Milk removed from a healthy udder contains a very low concentration with microorganisms, usually less than  $10 \times 10^2$  colony forming units of total bacteria per ml (cfu/ml). A camel with clinical or subclinical mastitis has the potential to shed large numbers of microorganisms in its milk. Several studies have investigated that quarters from infected camels have the potential to shed more than  $10 \times 10^6$  cfu ml<sup>-1</sup> in the produced milk. In the traditional husbandry systems, poor management and low hygienic standards during milking lead to mastitis in camels. Autochthonous microorganisms from the exterior of the camels udder and teats can contribute to the contamination as well as microorganisms that are derived from the environment in which the camel is housed and milked. However, the contribution of microorganisms from teats soiled with manure, mud and feed appears to be most important. Furthermore, under tropical and subtropical conditions, characterised by a lack of cooling and higher temperatures, camel raw milk can become contaminated after milking by storage and transport, especially if farmers store their milk in low hygiene plastic containers, and by the use of contaminated water. In such situations, the bacteria are able to grow rapidly and reached a total bacteria count of up to  $10 \times 10^7$  cfu ml<sup>-1</sup>. The types of bacteria that grow and become significant depends on the initial contamination of the milk. In conclusion, camel health, environment, milking procedures, equipment sanitation and storage and transport conditions can influence the level of microbial contamination of camel raw milk.

**Keywords:** Camel, mastitis, microorganisms, milk storage, milk transport, milking, raw milk

## Complementary Foods in Southwest Ethiopia: Diversity, Composition and Nutrient Adequacy

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At the age of six months and above, breast milk is no longer sufficient to meet nutritional needs of the growing infant. Nutritious complementary foods are therefore introduced. Understanding the diversity, nutritional composition, and nutrient adequacy of diets of young children is important in judging the adequacy of their diet, which was examined in this study. In this community-based cross-sectional study, a stratified multistage sampling procedure was used to sample 403 children, 6–23 months old, in Southwest Ethiopia. Data were collected using a semi-structured questionnaire. The dietary diversity score (DDS) was calculated as the count of food groups consumed in the 24 hours prior to the assessment among seven food groups. Six complementary foods predominantly fed to children were assayed for proximate composition, energy, mineral density, tannin and phytate content using standard methods. Nutrient adequacy ratio (NAR) was calculated as the intake of a nutrient (per day) divided by the recommended intake of the nutrient. Only 16.1 % of the children got the minimum dietary diversity. The children were reported to be fed with cereals & grains (68.8 %), discretionary calories (53.6 %), protein-rich foods (44.6 %), oils and fat (40.5 %), vegetables (38.5 %), fruits (28.1 %) and dairy products (17.9 %). The proximate composition and calorific value of the sampled foods ranged between 58.4–79.6 %, 8.2–11.9 %, 0.9–8.5 %, 2.3–8.2 %, 2.9–8.0 %, and 4.3–24.4 %, 27.9–162.6 Kcal/100 g for moisture, protein, crude fat, crude fibre, total ash, total carbohydrate and energy content, respectively. The mineral contents ranged between 22.5–42.4 mg/100 g, 1.8–4.1 mg/100 g, and 168.4–250.4 mg/100 g, 225.6–317.0 mg/100 g for iron, zinc, calcium and phosphorus, respectively. The phytate and tannin contents ranged from below detectable level (BDL)–117.7 mg/100 g and 1.2–75.2 mg/100 g, respectively. All the complementary food samples predominantly fed to children were not sufficient to meet the protein, fat, carbohydrate, energy and calcium requirements, (NAR<1). However, most of the diets provided adequate iron and zinc. The nutrient density and diversity of complementary foods of 6–23 months old children in the study area were found to be sub-optimal. Upgrading the nutritional composition of the predominantly starchy complementary foods should be of highest priority in order to improve the nutrition of infants and young children.

**Keywords:** Complementary foods, dietary diversity, nutritional composition

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## Optimisation of Cassava Foaming for Foam-Mat Drying, and Use in Cream-Based Foods

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Cassava foam was produced from cassava pulp (ca. 1.5°Brix, 1.005 g mL<sup>-1</sup>) by whipping two varieties of cassava (white-flesh from Costa Rica, & yellow-flesh, IITA-TMS-IBA 011368) with foaming agent (20% w/w GMS colloid) and stabiliser (NaCMC). Cassava foam was optimised for three independent variables: concentration of foaming agent (5 %, 10 %, 15 %), concentration of stabiliser (0.2 %, 0.4 %, 0.6 %), and whipping time (2 min, 4 min, 6 min). Using a Box-Behnken experimental design, two responses were measured: foam expansion (%) and foam density (g mL<sup>-1</sup>). Foam collapse (%) was also determined. Based on optimisation criteria of maximum foam expansion and minimum foam density, white-flesh cassava pulp required 14.97 % GMS, 0.51 % NaCMC, and 2.07 min to yield a foam of 52.63 % expansion, and density of 0.75 g mL<sup>-1</sup>. Also, yellow-flesh cassava pulp required 14.29 % GMS, 0.6 % NaCMC, and 2 min to yield a foam of 48.25 % expansion, and density of 0.76 g mL<sup>-1</sup>. Responses were adequately predicted by quadratic regression equations of the response surface method as 54.9 % foam expansion and 0.73 g mL<sup>-1</sup> foam density for white-flesh cassava foam; and 49.86 % foam expansion and 0.73 g mL<sup>-1</sup> foam density for yellow-flesh cassava foam. White-flesh and yellow-flesh cassava foams were stable, and both had low foam collapse of 1.79 % and 1.26 %, respectively. Foam produced was used to completely substitute milk cream in making of ice-cream; and as complement in salad mayonnaise. The cassava foam could also be dried into a foam powder for reconstitution. Preliminary results reveal foaming and drying white-flesh cassava foam powder at 55°C reduced total cyanogenic glucosides (assayed as total HCN equivalents) from 141.5 µg g<sup>-1</sup> to 20.5 µg g<sup>-1</sup>. Cassava foam substitution/complementation may be a healthy option suitable for vegetarians and vegans, and reduce need for animal fat in cream-based foods.

**Keywords:** Cassava foam, foam-mat, optimisation, response surface method, stabiliser

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## Status of Clean Milk Production in Faisalabad, Punjab, Pakistan

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Milk plays an important role in Pakistan's economy; 20 % of the milk comes from peri-/urban farms, is sold as untreated raw milk, therefore prone to fast spoilage and requires protection from contamination. This study aimed at determining factors influencing clean milk production in Faisalabad, the third-largest city of Pakistan. Using a semi-structured pretested questionnaire, interviews with semi-commercial small-scale (SCSS), commercial small-scale (CSS) and commercial large-scale (CLS) peri-/urban dairy households (HH, 60 per type) were conducted in February-March 2018, using snow-ball sampling. Interviewed HH had  $10 \pm 7.1$  years of dairying experience, kept  $12 \pm 9.4$  adult female buffaloes and  $12 \pm 7.1$  adult cows, earning about 1200 Euro month<sup>-1</sup> from milk sales. Differences in total number of dairy animals, earnings from milk sales and farm expenses between SCSS, CSS and CLS farms were significant ( $p < 0.001$ ). Two-thirds of the farms ( $n=136$ ) used traditional cow-sheds and 25 % had modern barns, with significant differences ( $p < 0.01$ ) in farm design, drainage system and cleaning frequency between SCSS, CSS and CLS farms. Flies and ticks were present in  $>80$  % farms but control measures only used in 22 % HH. Most animals (81 %) had dirt and dung coated bodies, hindquarters and udders. Practices like hair-clipping, hoof-trimming, udder-washing and teat-dipping were not applied by 83 %, 74 %, 59 % and 84 % of farmers, with significant differences ( $p < 0.01$ ) between SCSS, CSS and CLS farms. About 70 % of the workers didn't wash hands before milking; most (89 %) didn't trim nails nor cover heads (97 %) and carried on milking even in case of sickness (86 %). Milk cans were hardly disinfected (79 %) and milk mostly (64 %) stored in plastic containers without pre-filtration; however, CLS more frequently (50 %) stored milk in steel containers than SCSS (25 %) and CSS (20 %) farms ( $p = 0.001$ ). Most farmers (76 %) had no knowledge of farm hygiene, 62 % had little or no knowledge of clean milk production and 46 % no knowledge of improved farming practices, with significant differences ( $p < 0.01$ ) between farm types. While some reasons for unhygienic milk production, such as housing and drainage system, need major investment to improve, systematic cleaning of dairy animals, milking equipment and improved workers' hygiene can easily improve the milk safety in Pakistan's cities.

**Keywords:** Commercial dairy farming, public health, urban livestock keeping

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## **Milk Vending Machine Innovation for Retailing Milk: Operational Costs, Consumer Perceived Risks and Milk Quality**

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This study reports operating costs, consumer perceived risks and quality of milk from vending machines relative to other retailed milk. Data was collected using market and consumer surveys at the milk market outlets in five major towns in Kenya. The operating costs averaged KES 123,200 annually, of which 58.4 % was for servicing of the machine, 24 % for licensing and permits charged by regulating authorities and 17.5 % for water and electricity. Milk vending machine businesses sold between 200 and 1500 litres a day with a retail margin of KES 5 to 10 a litre of milk, generating returns to the business of KES 1,000 to 15,000 a day. For a litre of pasteurised milk, a consumer saves up to 50 % as compared to the price of packet milk when purchasing milk retailed from vending machine. A random sample of consumers associating retailed milk with high risks of adulteration, bacterial load, chemical preservatives, antibiotic residues or unhygienic handling were fewer for vending machine (11.1–16.8 %) than were for farm milk directly supplied to consumers (7.9 – 38.0 %), pasteurised packet milk (11.7 – 30.7 %) or mobile trader retailed milk (14.9 – 57.3 %). Compliance with microbiological quality was higher in milk samples from vending machine than for milk retailed in plastic containers (74.4 vs 31 % in TVC; 79.5 vs 41.4 % in TCC). However, milk contamination with aflatoxin AFM1 exceeded Codex standards of 50 ppt for milk from vending machines ( $120.87 \pm 24.63$  ppt) while milk from plastic containers ( $35.61 \pm 20.10$  ppt) did not. The number of milk samples found non-compliant was higher from vending machines compared to plastic containers (50.0 vs 63.6 %). Milk samples from vending machines did not offer better compliance in quality standards over milk from plastic containers in density (100 vs 100 %), not fat solids (46.6 vs 41.4 %), hydrogen peroxide (92.3 vs 96.6 %) or antibiotics presence (96.3 vs 93.1 %). Results show that servicing and licensing make up a large part of operating costs but returns to entrepreneurs are positive. Consumers associate milk retailed in vending machine with lower risks than milk retailed directly from the farm, mobile traders or in packets. However, consumers are exposed to the risk of aflatoxin contamination.

**Keywords:** Aflatoxin contamination, fresh milk, milk marketing, quality standards

## Status of Aflatoxin Contamination in Marketed and Farm Gate Milk in Nairobi County of Kenya

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In Kenya where milk consumption is higher than in other countries in the region, a major concern is the risk of chemical hazards in milk; particularly aflatoxins whose high levels have been reported. Milk contamination with aflatoxin M<sub>1</sub> (AFM<sub>1</sub>) has been causing public health concerns. Thus the aim of this study was to give baseline data on aflatoxin contamination in marketed and on-farm consumed milk in Nairobi County. To quantify the levels of aflatoxin in milk and milk products consumed in middle/high and low income areas of Nairobi, 291 samples were collected mainly from retail shops and selected supermarket. For the farm gate milk, 84 milk samples were collected from small holder dairy farms in urban and peri-urban areas. All samples were analysed for AFM<sub>1</sub> using enzyme-linked immunosorbent assay (ELISA). The levels of AFM<sub>1</sub> in the milk and milk products ranged from 0.30-1069.45 ppt in low income area with over 66 % of samples exceeding the EU legal limit of 50 ng kg<sup>-1</sup>, whereas contamination levels ranged from 0.94-1078.49 ppt in samples from higher income area wherein 40% exceeded the EU legal limit. Although farm gate milk samples had lower AFM<sub>1</sub> levels (range: 1.73-255.96 ppt) when compared to market milk samples, over 64 % had levels that exceeded the EU legal limit. The population in these regions is at high risk to AFM<sub>1</sub> exposure, thus necessitating the need to explore different mitigation strategies to control AFM<sub>1</sub> contamination in milk and milk products in Nairobi county of Kenya.

**Keywords:** Aflatoxin M<sub>1</sub>, dairy farms, ELISA, exposure, milk, Kenya

## **Mycobiota, Total Aflatoxin Levels and Quality Assessment of Smoked Dried Juvenile Fish (*Clarias gariepinus* (Lori Amala)) from some Major Markets in Ibadan Metropolis, Oyo State, Nigeria**

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The contamination of food due to the occurrence of mycotoxigenic fungi is a public health concern. Therefore, fungi contamination and total aflatoxin levels of smoked dried juvenile fish samples *Clarias gariepinus* (Lori amala) were investigated. A total of 20 samples of smoked dried juvenile fish were purchased from some major markets in Ibadan. The total fungi count ranged from  $1.0 \times 10^3$  –  $12.0 \times 10^3$  CFU g<sup>-1</sup>. A total of 32 fungal strains isolated from the samples include: *Aspergillus niger*, *Aspergillus flavus*, *Penicillium* sp., *Rhizopus* sp., *Alternaria* sp., *Aspergillus ochraceus*. *Aspergillus niger* had the highest frequency of occurrence (38 %) while *Aspergillus ochraceus* (3 %) had the lowest. All the samples were contaminated with aflatoxin. The total aflatoxin content ranged from 0.237 ppb to 1.995 ppb. The levels of aflatoxin contamination were within the maximum limit permitted. Out of the 11 *Aspergillus* strains obtained from the samples, 5 were aflatoxigenic while 6 were non-aflatoxigenic. 85 % of the mycobiota were xerophilic in nature and 94 % were halophilic in nature. The percentage moisture content, crude protein, crude fat and ash content in the samples ranged from 12.99 – 17.82 %, 68.72 – 77.62 %, 0.49 – 6.00 %, 6.97 – 12.24 %. The P, K, Ca, Mg, Fe, Cu, and Zn of the smoked dried juvenile fish samples ranged from 388.2 – 509.6, 1113.8–1517.0, 928.7 – 1518.8, 129.0 – 241.8, 13.37 – 61.25, 0.193 – 0.805, 5.228 – 7.690 mg/100 g. Pb and Cd were not detected in the samples. The levels of aflatoxin contamination in this study were within the maximum limit permitted of 20ppb. Therefore, proper attention is needed for adequate preservation before sales and consumption.

**Keywords:** *Aspergillus niger*, crude protein, dried juvenile fish, mycotoxigenic fungi, total aflatoxin

## Screening of PAHS Concentrations in Traditionally Smoked Freshwater Fish Products from Tonle Sap in Cambodia

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More than 85 % of the population in Cambodia is strongly dependent on agriculture, especially the fishery industry. Freshwater fish meat and products are one of the main sources of Cambodians income. The low living standards result in a lack of access to electricity, which affects 66 % of the population in Cambodia. Thus, smoking as one of the oldest preservation method is still widely used in the country. Potential health hazards associated with smoked foods may be caused by carcinogenic components of wood smoke – mainly polycyclic aromatic hydrocarbons (PAHs). Smoked fish represents important source of nutrients for the Cambodian population. However, this also leads to an excessive intake of PAHs produced during traditional smoking of fish. Traditional techniques of smoked fish production in Cambodia had not been fully investigated. Therefore, a field study was conducted among selected smoked fish producers near Tonle Sap river in Kampong Chang province, Cambodia, and questionnaire survey within 5 provinces (Kampong Chhnang, Battambang, Siam reap, Kampong Cham) in Tonle Sap area, Cambodia. During the research, 23 samples from 10 producers were collected. Extraction of completely homogenized samples by Soxtec apparatus was followed by pre-cleaning by gel permeable chromatography (GPC). Analytes in recupered eluate were evaluated by high performance liquid chromatography with fluorescence detector (HPLC-FD) for analysis. Identification based on comparison of retention times with standards, quantification was performed by method of external standard. The study revealed that maximal limits (ML) for a sum of 4 PAHs and BaP given by EC 1881/2006 were exceeded between 2 to 60 times ( $34.25 \mu\text{g.kg}^{-1}$  to  $597.75 \mu\text{g.kg}^{-1}$ ) and 2 to 50 times ( $4.58 \mu\text{g.kg}^{-1}$  to  $119.45 \mu\text{g.kg}^{-1}$ ), respectively. Such burden can lead to an increased risk of development of carcinogenic diseases and other diseases related to PAHs exposure. Further investigation and research focused on concentration on the amounts of PAHs per gram of fish consumed or fat content is recommended.

**Keywords:** Cambodia, food chain, freshwater fish, pollutants

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## Traditional Smoking of Freshwater Fish in the Western Region, Cameroon

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The West region of Cameroon has a high demand for innovative and healthy solutions for fresh water fish conservation. Smoking, drying and salting were the three fish conservation methods identified in the Noun Division. Of all these methods, smoking was predominantly (75 %) practiced. An evaluation of socio-economical characteristics of fish smokers was conducted. The results of this study showed that fish smoking is practised mainly by women (70 %) which is common in the Cameroonian small scale fish sector, aged from 20 to 50 years (80 %), and married (91.2 %) and taking care of a family of 1 to 10 persons (80 %). These smokers are Muslim (74 %), belonging to the Bamoun ethnic group (81 %). They were also involved in other activities: agriculture (29 %) and trade (1 %). About 67 % of the sampled population had an experience of more than 10 years. The purpose of smoking was largely sales (97 %) and subsistence (3 %). *Oreochromis niloticus*, commonly called Nile tilapia, was the most smoked species (36 %), followed by *Clarias gariepinus*, called African catfish (32 %). The average quantity of fresh fish smoked was 110 kg/day/smoker, with *Oreochromis niloticus* having a higher production level ( $60 \pm 4.74$  kg/day/smoker). With regard to the smoking techniques used, hygiene measures were poorly respected. This study revealed that freshwater traditional fish smoking activities in Noun Division are influenced by gender, economic and cultural aspects. Also, these activities are constrained by a lack of technical support material and financial means. Any investigations on the implication on health and food safety will be suitable for fresh fish smokers and the consumers. The environmental impact of smoking efficiency and methods on forest depletion is to be monitored and assessed in further investigations.

**Keywords:** Cameroon, continental waters, fish conservation, processing

## Alga and Insect Meal and their Effect on Monogastric Animal Meat Quality

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Access to appropriate feedstuffs improves the production efficiency of meat products; therefore increasing access to protein and vitamin rich food, globally. In most Western countries, soybean is the customary protein source in chicken and swine diets. However, the soybean market remains dominated by strong demanding (e.g. China, EU) and supplying (e.g. Argentina, USA) countries; therefore this feedstuff is not as secure for more decentralised producing regions, as exist throughout the (sub-)tropics. Currently, *Spirulina* (*Arthrospira platensis*) is being reincorporated into livestock diets in Southeast Asia and black soldier flies (*Hermetia illucens*) are considered an acceptable livestock protein source as they can be produced on-farm with manure as a substrate. Using Ross 308 broilers and Pietrain × (Large White × Landrace) barrows we ascertained the effects of *Spirulina* or partially defatted black soldier fly larval meal on chicken meat and pork quality, compared to the Western standard soybean diet. In order to achieve industry acceptable growth, the diets were supplemented with amino acids, where *Spirulina* animals needed to be supplemented to a higher level than the insect-fed animals, and chickens required more supplementation than swine. When diets achieved amino acid requirements, multiple meat quality differences existed for chicken. Live weight, carcass weight, thigh weight, pH20min, pH24h, drip loss, and lean colour of skinless breast and thigh cuts were significantly different between groups. *Spirulina*-fed meat had a stronger umami and chicken taste, as well as it smelled less ‘animal-y’ when cooked and insect-fed samples had a reduced adhesive texture while being chewed, as determined by a trained sensory panel. Few differences were observed in pork – differences included carcass weight, cooking loss (%), and pH45min, where insect-fed animals produced heavier carcasses than the *Spirulina*-fed, had a higher pH45min, and exhibited reduced cooking losses. Both protein alternatives resulted in meat with a stronger odour when cooked and *Spirulina*-fed samples tasted more astringent, whereas insect-fed samples were juicier. These results suggest that both alternatives could be integrated into monogastric animal diets, but further research should focus on the acceptance, especially poultry product colour, of these alternative products in local markets.

**Keywords:** Animal nutrition, black soldier fly, broiler, *Hermetia illucens*, meat-type chicken, pork, *Spirulina*

## Potential Application of Chitosan Nanoparticles Derived from Marine Fish Scales as Preservatives for Fishery Products

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The establishment of nanotechnology to convert raw biomass material to useful lower weight molecules is potentially applied to produce chitosan nanoparticles as a food additive and preservative. This study aims to develop chitosan and its nanoparticles derived from chitin of different marine fish species as nutraceuticals for improving food quality, in particular as natural preservatives for fishery products by evaluating its nutritional values and antibacterial properties. The fish scales wastes of five marine fish species were used as raw materials for chemical extraction of chitin and further processed to become chitosan following the standard steps of deproteination, demineralisation and deacetyation. Chitosan was molecularly proven using Fourier Transform Infrared Spectroscopy (FTIR). Nanochitosan was prepared by adding drop wise a tripolyphosphate-pentasodium solution to chitosan solutions under stirring. Results of compositional analysis of the fish scales revealed that protein content was high (25–32 %), as well ashes (36–45 %) which attributed to minerals, while carbohydrates (12–19 %), and fat (4–7 %). Chitin yields (%) ranged from 17 to 61 %. Chitosan is a derivative of chitin if the percentage of diacetyl degree exceeds 50 %. The absorption bands of FTIR of chitosan were within the range of standard chitosan. Nanoparticles of chitosan were obtained as particulate dispersions or solid particles with a size in the range of 255 to 438 nm. Nanoparticles of chitosan were sprayed onto the surface of the fishery products. Improved nutritional value of the nanoparticle coated products and its antibacterial ability have been proven. Nutraceutical applications of chitosan nanoparticles are discussed along with considering variation in the type of fishery products and storage duration.

**Keywords:** Chitosan, fish scales, fishery products, nanoparticles, preservatives

## **Current Status of Pre-Slaughter, Slaughtering and Post-Slaughter Handling Practices Affecting the Quality of Fresh Meat in Pastoral Areas of Kenya**

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Meat quality and safety is dependent on proper pre- and post-slaughter handling practices in abattoirs and meat outlets. The meat value chain in Kenya is challenged with a myriad of problems due to poor pre-slaughter, slaughtering and post-slaughter processes. Poor practices can lead to serious contamination and spoilage of meat and meat products. These losses in the meat value chain predispose the livestock communities who are majorly dependent on pastoralism to food and nutritional insecurity as well as loss of income. There is limited data and knowledge gap with regards to post-harvest handling and preservation of meat in Kenya especially the pastoral regions. Hence the need for these present findings. This study was, therefore, designed to analyse and validate pre- and post-slaughter handling practices that contribute to the poor quality and safety of meat and meat products in Kenya. Mixed research methods using a pretested structured questionnaire, key informants interviews and focus group discussion were used to collect data from four pastoral counties including Marsabit, Turkana, Garissa and Kajiado counties. The selected livestock facilities included abattoirs, slaughter houses, butcheries, and other meat selling outlets. The findings of the study shown that 90 % of the selected facilities involved in meat production and processing have poor handling practices. About 40 % of the meat operators in Nairobi had poor hand washing practices with personnel from facilities in pastoral regions indicating 60 % non-compliance to hand washing. Results also show that 65 % of the personnel operating in the meat facilities were not using personnel protective clothing in Nairobi and 88 % in pastoral areas. Poor transportation practices were shown with 38% of meat being transported in metallic boxes mounted on a motorbike in urban towns while 26 % in boxes mounted on bicycles in rural pastoral areas. Meat quality deterioration was caused mainly by unhygienic handling practices (80%). In the slaughter operations, extreme hot weather conditions, inadequate water supply, long distances and lack of refrigeration facilities accelerated spoilage. To enhance the meat safety and quality, interventions are required along the hot spots identified along the meat value chain in Kenya. The adherence to best practices in meat production and practices can lead to better meat quality and competitive market prices for meat products in Kenya.

**Keywords:** Microbial contamination, post-slaughter, pastoral regions, slaughtering

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## Intelligently Designed Electrochemical Platform for the Detection of Food Contaminants

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Food safety is a challenge to human health worldwide and specifically in developing countries. Continuous monitoring of food contaminants through novel and sensitive analytical techniques is a must to ensure food safety. Among these contaminants are veterinary drugs broadly used by veterinarians to control farm animal diseases. These drugs and their metabolites are usually carried over to edible animal tissues, eventually imposing negative health effects on consumers. The European Union (EU) has established a set of maximum residual limits (MRLs) for veterinary drugs and other food contaminants. Detection of food contaminants mainly depends on separation techniques such as liquid or gas chromatography coupled with mass spectrometry or immunological interaction assays, such as enzyme-linked immunosorbent assay. Despite being sensitive and specific, all these techniques require expensive equipment and highly trained personnel, which limit their applications in developing countries with poorly equipped facilities and specialists. To overcome this, nanomaterial-based biosensors have been proposed as a rapid, sensitive, efficient and portable alternative to traditional detection techniques. In the present work, we demonstrate a novel electrochemical sensor fabrication technique for trace determination of diminazene, a veterinary drug commonly used in dairy animals and present in their milk. The MRL set by the EU for the presence of this compound in milk is 150  $\mu\text{g L}^{-1}$ . The new sensor has been fabricated using nickel ferrite nanoparticles ( $\text{NiFe}_2\text{O}_4$ ) modifying the carbon paste electrode (CPE), together with an ionic liquid. The modified CPE showed a synergic effect toward the oxidation of diminazene. The prepared nanoparticles were investigated and characterized using different techniques, and the described voltammetric technique was optimized and validated. Under optimal conditions, the sensor showed a sensitive response to diminazene over a wide linear range. Finally, the developed method was used to quantify traces of diminazene in milk samples.

**Keywords:** Carbon paste, electrochemical detection, food contaminants, nickel ferrite nanoparticles, voltammetric sensor

## The Uneven Spread of Private Food Quality Standards Over Space and Time

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In response to discerning consumers worldwide, retailers increasingly demand compliance of stringent standards with requirements for food quality and safety, for environmental sustainability and for labour standards. The GlobalG.A.P. standard, being the most prominent global private agri-food pre-farm gate process standard, increased by almost six folds between the mid-1990s and 2011. As a result, many agricultural producers across the world are embracing GlobalGAP as an entry ticket to high-value (mostly) European and US markets. However, over the last two decades, also in developing countries, the retail-sector has undergone a tremendous transformation from traditional retail systems to modern grocery stores. Market power structures of retailers versus farmers make compliance by farmers in developed and developing countries de-facto mandatory to access high-value markets. However, the global spread of important certification schemes is highly unequal. While some regions perform well in adjusting to the sector's transformation, other world regions lag behind and show low certification rates of farmers. These unequal patterns of the global diffusion of food quality standards remain poorly understood, as neither the underlying macroeconomic determinants of standard adoption nor the dynamics over time have been thoroughly investigated. The study seeks to fill this research gap and find the country-level factors that explain this uneven spread, conceptually grounding on the theoretic field of organisational innovations. Findings show that the degree of supermarket distribution in a country and governance structures explain why countries can enter certification markets for the first time. A favourable business environment, high quality of infrastructure, and existing strict public regulations explain an intensification of certification rates. These findings provide important policy implications. To promote the further expansion of certification within countries, public and private investments in modern retail systems seem an appropriate means. Moreover, connecting rural production areas to urban centres by infrastructure investments should help to further spread private food standards.

**Keywords:** Certification, diffusion of innovations, global value chains, GlobalGAP, market access, private food standards

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## Small-Scale Post-Harvest Processing of Underutilised Fruits and Vegetables – A Framework for Assessing Economic Viability

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Over recent years, a growing body of research has pointed towards the great potential in processing underutilised fruits and vegetables (UFV) into highly nutritious food products, to prevent micronutrient deficiencies among vulnerable populations in sub-Saharan Africa. Approaches which tap into this potential, however, have not been adopted at a significant scale by smallholder farmers and rural entrepreneurs in Western Africa. Consequently, post-harvest losses remain high and traditional processing methods, such as sun drying, which tend to adversely affect the quality and safety of food products, continue to be the most prevalent form of food processing. A key limitation in the dissemination and uptake of modern processing for underutilised species is the lack of information on market barriers, as well as economically viable and context appropriate business models. Based on an extensive literature review, key market and economic barriers for small-scale renewable energy driven processing of UFV in Western Africa have been identified and a preliminary theoretical framework for the assessment of economic viability developed. Results point towards an often insufficient understanding of customer preferences as a major source of overestimation of willingness to pay and demand development for high-nutrient processed foods, as consumption of UFV often varies widely throughout countries and reliable data are rarely available. Short, pronounced harvest seasons for UFV pose key considerations for the economic viability of small-scale processing. Based on the availability of UFV, processors are oftentimes required to produce a large share of their annual production during a short time window following rainy seasons. Apart from cash flow and storage constraints, this can result in a business model which conflicts with the economics of renewable energy driven technologies, whose high investment costs and near zero running costs dictate a maximisation of annual capacity utilisation. In a next step, the developed framework will be verified using data from Nigeria and Sierra Leone, collected through semi-structured interviews with UFV traders and local farmers. Results will be used to inform the development of context appropriate business models within UPGRADE Plus, a BMEL funded research project on decentralised post-harvest processing of UFV to promote food and nutrition security in Western Africa.

**Keywords:** Business models, decentralised renewable energy technologies, economic viability, market barriers, post-harvest processing, underutilised fruits and vegetables

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## Postharvest Handling Factors Affecting Antioxidant Content of Horticultural Plants: A Review

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Nutritional guidelines recommend high consumption of fruits and vegetables as protective against cardiovascular diseases, different types of cancer. Intended to reduce loss and maintain quality of fruits and vegetables till the consumption, postharvest techniques including storage (temperature, time and humidity), fresh cut, modified/controlled atmosphere packaging and chemical treatments perform differently, affecting the quality and antioxidant properties of fruits and vegetables during the postharvest handling. This review aimed to document and highlights the effect of some postharvest handling factors on the antioxidant content of horticultural plants. The review showed that low storage temperature is in favour with vitamin C retention. Temperature effect on antioxidant capacity varies according to fresh produce. Though fresh cut is a convenient practice, it negatively affects vitamin C content of fruit and vegetable except for pineapple. Carotenoids seem more stable though some mild reduction effect can be observed in selected fruit as induced by fresh-cut practices. Controlled/Modified atmosphere may be considered as a good way to monitor vitamin C content in fruit and vegetable. Total phenolic content tends to remain constant or increase with storage in modified atmosphere packaging (MAP). The review suggests that postharvest handling is performed in conditions that preserve maximum nutrients and antioxidants. There is a need to put research effort in investigating the effect of the postharvest techniques on antioxidants of typically local African food resources which have been given little attention in the past despite of their high nutritional advantages. This would help people of this region, especially those in rural areas who heavily depend on the local food resources to maintain an acceptable food diet during the lean seasons; hence contributing to the global goal of food security.

**Keywords:** Antioxidants, fruits and vegetables, post harvest handling



## Quality Changes of Different Varieties of Sweetpotato under Curing Condition

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Sweetpotato (*Ipomoea batatas*) has become an important cash crop that is commercially planted in Malaysia. Most sweetpotato varieties in Malaysia are marketed in fresh form. Proper postharvest handling techniques must be applied to ensure that the quality of harvested tubers is preserved along the marketing chain. Based on this current situation, the suitability of adopting curing techniques during postharvest handling of Malaysian varieties of sweetpotato needs to be investigated. The objective of this study was to determine the effect of curing on quality changes of the Malaysian sweetpotato varieties of purple and orange flesh. The crop was harvested at 16 weeks after planting and cured for 4 days in a curing chamber at 29°C and 85 % relative humidity (RH). The results indicated that cured tubers had a minimal weight loss of less than 1 % up to 4 days of the curing period. Weight loss was observed to be highest for uncured tubers at 4.7 % on the 4th days under ambient conditions. The purple flesh variety showed a higher weight loss in comparison to the orange flesh variety. Total antioxidant activity and flesh colour were stable and remained unchanged throughout the curing periods for both varieties but the total phenolics content was retained better at 44.56  $\mu\text{g g}^{-1}$  for the cured purple flesh variety as compared with uncured tubers while the retention of total phenolics in the orange flesh variety was 4 times lower at 11.093  $\mu\text{g g}^{-1}$  at the end of the curing period. Sprouting incidence for both varieties can be observed on the third and fourth day of the curing period and it was found to be higher in cured tubers of orange flesh variety at 4.00% as compared with 1.33 % in the purple flesh variety. The texture of the cured tubers of purple flesh variety was firmer at 22.192  $\text{N m}^{-2}$  as compared with orange flesh variety at only 18.615  $\text{N m}^{-2}$ . The study indicated that purple flesh variety had shown a better quality after curing than orange flesh variety. Curing for 2 days is recommended for both varieties due to better product quality.

**Keywords:** Curing, Malaysian varieties of sweetpotato, quality changes

## Metagenetic Analysis of the Bacterial Community Composition and Dynamics in Fermenting Enset (*Ensete ventricosum*)

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Enset (*Ensete ventricosum*) provides staple food for over 15 million people in Ethiopia after fermentation into kocho. The fermentation has hardly been investigated and is prone to optimisation. The aim of this study was to assess the bacterial community composition and its dynamics during enset fermentation using Illumina Miseq sequencing. To this end, three predominantly used enset varieties (Gena, Maze and Ketishe) were processed and allowed to ferment for two month in a bamboo basket, also called 'erosa'. For each variety, fermenting enset samples from days 1, 7, 17, 31 and 60 were subjected to high-throughput 16S ribosomal RNA gene sequencing via the Illumina MiSeq platform. A visual comparison between bacterial community compositions from different fermentation days (non-metric multidimensional scaling) showed that samples were highly dissimilar on day 1, both between and within different varieties. During fermentation, samples evolved to a more similar bacterial community composition and as from day 31 and continuing until day 60, samples from all varieties had reached a comparable bacterial community composition. The most important similarities on day 1 were the presence of a bacterium assigned to the family Enterobacteriaceae with a relative abundance of 22.9 %, 28.2 % and 17.7 % and the lactic acid bacterium *Leuconostoc mesenteroides* (29.7 %, 9.5 % and 13.9 %) for Gena, Maze and Ketishe, respectively. In addition, the varieties Gena and Ketishe harbored the aerobic bacterium *Nocardiopsis* sp. (14.2 % and 24.6 % respectively) but this bacterium was absent in Maze. Another unequivocal observation from the metagenetic profiles was that the genera *Dysgonomonas* and *Clostridium* as well as *Prevotella* *paludivivens* were found in a very low abundance, but in a consistent way. *Dysgonomonas* is reported to cause gastroenteritis in immunocompromised persons. As the genus *Clostridium* contains pathogenic species as well as spoilage organisms, further research is necessary to elucidate the safety of fermented enset. Overall, *Leuconostoc mesenteroides*, initiated the fermentation. Later on, *Prevotella* *paludivivens*, *Lactobacillus* sp. and *Bifidobacterium* *minimum* dominated. These three species are potential candidates for the development of a starter culture to optimise enset fermentation.

**Keywords:** Enset, fermentation, kocho, metagenetics, starter culture

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## Influence of Cultivar and Plant Age on Cyanide and Protein Contents in Thai Cassava (*Manihot esculenta* Crantz) Leaves

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Cassava leave is one of the major global wastes from the agricultural sector. It has a significant content of protein, vitamin C, carotenoids and chlorophyll. Recently, the utilisation of cassava leave in Thailand has been rare due to its toxicity from cyanide. In this study, the influence of cultivar and plant age on cyanide and protein contents in cassava leaves was studied. Four cultivars were selected. Cultivar Hanatee and Rayong 2 were representing a sweet type, while cv. Rayong 5 and Kasetsart 50 were representing a bitter type. The leaves were collected from cassava plants at six and twelve months after planting. They were harvested from the branch at seventh to ninth row from the top of the plant. Cyanide content and crude protein in the leaves were investigated. The results showed that in general cultivars affected the cyanide content in the leaves for both plant ages. The cultivar Kasetsart 50 had the highest cyanide content in the leave with a concentration of  $2330.18 \pm 152.08$  and  $2209.92 \pm 162.30$  ppm HCN equivalent (dry basis) for six and twelve months plant ages, respectively. When the plant was matured for harvesting its root (twelve months), cultivars did not show significantly impact on protein content in the leaves. The protein content in the leaves from both sweet and bitter types at crop harvesting period were in the range of  $23.17 \pm 1.37$  to  $25.61 \pm 1.96$  g/100 g dry basis. In contrast, the protein contents in the leaves from six months old plant were significantly different depending on cultivars. At this plant age, the bitter type showed higher protein contents compared to those sweet varieties. The protein contents were  $34.82 \pm 1.54$  and  $31.21 \pm 0.98$  g/100 g dry basis for cv. Rayong 5 and Kasetsart 50, respectively. The impact of cultivar and plant age on other nutrients such as vitamin C and carotenoids in the leaves is under investigated. The outcome will not only enhance the farm waste management but also introducing cassava leaves as a substitution source of protein in human nutrition for the cassava growing countries which are mostly under developed countries.

**Keywords:** Cassava, cyanide, farm waste, nutrient, protein

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## Assessment on Carotenoids Profile Extracted from Mango Peel via Accelerated Solvent Extraction and Ultrasound Assisted Extraction

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Mango (*Mangifera indica* Linn) is an important tropical fruit and is associated with civilisation due its nutritional and sensory properties. Phytochemical composition of mango has shown the presence of up to 25 different carotenoids, with a total concentration of around 200  $\mu\text{g/g}$  DW and  $\alpha$  and  $\beta$ -carotene the most representative ones. The identification of technologies capable of isolation this valuable compounds is key for the valorisation of natural resources in a clean, efficient and low-cost manner. Therefore, the aim of this work was to evaluate the effect of Accelerated Solvent Extraction (ASE) and Ultrasound Assisted Extraction (UAE) on the extraction of carotenoids from three varieties of mango peel, an industrial waste presenting a potential source of interesting valuable compounds.

In first instance, five different solvent systems were screened in a two step extraction: (1) methanol, (2) hexane:ethanol (50:50; v:v), (3) hexane + ethylacetate, (4) hexane:ethylacetate (50:50; v:v) and (5) acetone:methanol (70:30; v:v) + methanol:dichloromethane (50:50; v:v); in all systems the mango:solvent ratio was 1:10 (m:v). The last solvent system, based on acetone:methanol, followed by methanol:dichloromethane was found to result in the highest total carotenoid extraction and was selected for the comparison of ASE and UAE. In order to extract up to completeness, both extractions were carried out for 45 min; after that, the solvents were evaporated and the carotenoids were re-dissolved in DCM prior to analysis. The results obtained through Ultra Performance Liquid Chromatography-accurate mass-mass spectrometry (UPLC-am-MS) showed that both methods are useful for extracting the same concentration of carotenoids; nevertheless, UAE allowed the quantification of a higher number of compounds. Overall, the results obtained provide a basis for the potential application of UAE as extraction technique for carotenoids, since it allows the use of a lower concentration of solvents, giving a character of “green technique”.

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**Keywords:** Mango

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## Total Phenol and Antioxidant Potentials of Provitamin A Cassava Peels and Stem Extracts

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The economic value of cassava plant may be enhanced through a complete utilisation of all the parts through a reduction, recycling and reuse of residues/by-products. Thus, this study was carried out to evaluate the potentials of extracting antioxidants and phenols from cassava peels and stems. Extraction was made from dried peel and stem samples using 80% methanol and the extracts were stored at -23°C until needed for further analysis. Average total phenolic (TP) yield from the extracts were 584.52 Gallic acid equivalent (GAE) mg/100 g (peel) and 272.47 GAE mg/100 g (stem) and 1, 1-diphenyl-1-picrylhydrazyl radical scavenging activity was 18.93% and 20.77%, respectively. The peel and stem extracts assayed by ferric reducing antioxidant power method had significant effect ( $p < 0.01$ ) on the antioxidant activities ranging from 101.50–169.50  $\mu\text{M TE g}^{-1}$  for the peel and 73–120.13  $\mu\text{M TE g}^{-1}$  for the stem. The findings in this study suggested that the peel and stem particle sizes influenced the extraction of antioxidants and the samples particle sizes were dependent on the solvent, the incubation time and the antioxidant assays used. The presence of the antioxidants in the extracts is an indication of the total phenol content, 1, 1-diphenyl-1-picrylhydrazyl scavenging activity and ferric reducing antioxidant power. These substances can serve as valuable source of raw materials for food and non-food applications.

**Keywords:** Ferric reducing antioxidant power, gallic acid equivalent, antioxidant activity, provitamin A, radical scavenging activity

## Assessment of Iron and Copper Composition of Selected Underutilised Vegetables of South Western Nigeria

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Vegetables are sources of nutrients, vitamins, proteins, anti-oxidants and fibre needed by the human body for growth. A closer look at the vegetable content of the diets in South Western Nigeria revealed that very few vegetables are routinely included in the diet compared to the abundance of vegetables in the area. This can be attributed to the inadequate knowledge of dietary and medicinal use of some of these plants. This study assessed the Copper and Iron composition of selected underutilised vegetables of this geographical area with the view to evaluate their nutritional qualities. The vegetable crops used in this study are: Ewuro (*Vernonia amygdalina*), Elegede (*Cucurbita maxima*), Ugu (*Telfaria occidentalis* Hoof), Worooowo (*Senecio bialfræ*), Ebolo (*Crassocephalum rubens*), Ogunmo (*Solanum nigrum*), and Igbagba (*Solanum aethiopicum* L). The vegetable crops were grown on the fertility plot of the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife. The vegetable leaves were collected at three points of time and plant tissue analysis was carried out. The iron and copper composition of the leaf tissue were determined using Atomic Absorption Spectrophotometer (AAS). The result showed that copper content ranged between Worooowo (0.31 mg kg<sup>-1</sup>) and Ogunmo (0.11 mg kg<sup>-1</sup>) while the highest iron concentration was observed in Elegede (8.18 mg kg<sup>-1</sup>) and the lowest in Ewuro (1.00 mg kg<sup>-1</sup>). The concentration of copper in these vegetables is illustrated in a descending order; Worooowo > Ebolo = Ewuro > Ugu > Igbagba > Elegede > Ogunmo. The iron concentration of these vegetables is also illustrated in a descending order; Elegede > Ebolo > Ogunmo > Worooowo > Igbagba > Ugu > Ewuro. The study concluded that the composition of iron and copper in these vegetables are within the standard recommended for good health and therefore these vegetables are good for human consumption and could prevent micronutrient deficiencies in people who consume them.

**Keywords:** Copper, iron, Nigeria, vegetables

## Antimicrobial Efficacy of Lemongrass (*Cymbopogon citratus*) and Fingerroot (*Boesenbergia pandurata*) Essential Oils against Foodborne Pathogens

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The consumption of ready-to-eat meat products such as sausages, meatloaf, dried meat and cakes is increasing mainly in developing countries. Meat is still one of the most important components of human diet due to its high protein content. However, the risk of contamination with foodborne pathogens from poorly processed and stored meat products, such as salmonellosis, *Escherichia coli* and other pathogens pose a great health hazard that needs to be controlled. Presently, these pathogens are being controlled with the aid of synthetic or natural preservatives. However, concerns about the safety of chemical additives (such as chlorides, nitrites, sulphites, etc.) have been on the rise at an alarming rate in recent years. As a consequence, consumers are progressively demanding the use of natural products as alternative for synthetic preservatives. Thus, this study investigates the potential of essential oils of Lemongrass (*Cymbopogon citratus*) and Fingerroot (*Boesenbergia pandurata*) as a natural preservative to control four common foodborne pathogens (*Listeria monocytogenes*, *Staphylococcus aureus*, *Escherichia coli* and *Salmonella Enteritidis*) *in vitro*. Firstly, the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) was measured using the multiple tube dilution method and colony-forming assay, respectively. Secondly, a storage assay was conducted, wherein different concentrations (MIC, 2xMIC, 4xMIC) of the essential oils were tested for their effectiveness at two different storage temperatures; refrigerated temperature (4°C) and room temperature (25°C) for five days. Results indicated that both essential oils manifested antibacterial activity against all tested pathogens at both storage conditions mentioned above. The MIC at 4°C varied from 0.03 to 0.25 % and at 25°C varied from 0.06 to 0.50 %. Lemongrass EO showed lower MIC and MBC than fingerroot EO against all tested bacteria. This study suggests the potential usage of natural essential oils as antimicrobial preservatives, which could be used as alternative additives in foods.

**Keywords:** Antibacterial, essential oil, fingerroot, lemongrass, natural preservatives

## Performance Evaluation of an Inflatable Solar Dryer for Maize and the Effect on Product Quality Compared with Traditional Sun Drying

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Maize is an important food source in Uganda, where the daily consumption is 52 g per person. Maize is often harvested at a high moisture content not suitable for long-term storage. Therefore, drying is a crucial process to slow down the activity of enzymes, bacteria, yeasts and moulds; and to preserve the quality before storage. Traditionally, maize is dried by spreading the grains on a surface under direct sun. In these conditions the risk of contamination is high and it is difficult to achieve required reduction of moisture content during cloudy weather. In this study, maize was dried using an inflatable solar drier (ISD) and the performance was compared with traditional sun drying in Gombe, Wakiso District in the Central Region of Uganda. The quality of maize, in terms of the contamination level of yeast, moulds and aflatoxins, was evaluated. The target moisture content for safe storage could be achieved in less than one day using both drying methods, whereas no significant difference of drying time was detected at  $p \leq 0.05$ . The ambient temperature during the field trials varied between 16 and 32°C, while ambient relative humidity was between 40 and 90 %. The maximum temperature inside the ISD could reach up to 68°C, which was around 25°C higher than the ambient. The variation in relative humidity inside the ISD depended on the ambient relative humidity and reached a maximum of 89 %. Aflatoxin contamination was analysed and compared to the EU standard limit of 10 ppb. Some batches showed a contamination lower than the standard limits while in one batch, contamination was manifold higher. In general, the batches dried under ISD showed a slightly lower contamination compared to the sun dried samples. Application of ISD showed a great potential to preserve the quality of maize. A rapid and non-destructive method to determine the quality of maize should be developed for early detection of the contamination along the whole value chain.

**Keywords:** Drying characteristics, food quality control, food safety, innovative solar drying, mycotoxin, solar bubble dryer

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## Quality Evaluation of Hot Air-Dried Mangoes through Heat-Sensitive Enzymes

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Mango fleshes has a great importance due to its rich nutritional value as well as being a good source of enzymes. Presently, different heat processing techniques are being used to preserve mango for longer shelf life. Drying at a higher temperature not only decreases the nutritional value of the dried fruit but can also cause the destruction of the enzyme active sites. Thus, to assure the production of high value dried product, a new system to test the quality of the dried fruit needs to be developed and drying techniques need to be optimised. In this study, the activity of heat sensitive enzymes (HSE) was estimated to test the quality of hot air dried mango. The selected mango varieties (S. B. Chaunsa, Sindri) from Pakistan and Tommy Atkins from the local market of Stuttgart were obtained and dried with a hot air oven (40°C, 50°C, 60°C, 70°C and 80°C). The system was operated in over-flow mode and samples were dried to the target moisture level below 15 % (d.b.) with  $a_w \leq 0.6$ . The differences between the variables were tested for significance level ( $\alpha=0.05$ ) by one-way ANOVA and Tukey's HSD post hoc multiple range test. During drying, the activity of HSE in all three mango varieties was significantly ( $p < 0.05$ ) decreased (45–97 %). However, the maximum activity of HSE (45–68 %) was attained when drying at 40°C while the lowest one (3–13 %) was at 80°C. From the results, conclusions can be drawn about drying temperature favourable for high enzyme retentions or for high enzyme degradations. The residual enzyme activity in the dried sample can be used as a parameter to provide information about the drying operational temperature and ultimately about the product quality.

### Practical Application

The research work can be used in the drying industry to test the quality of the dried mangoes.

**Keywords:** Heat processing techniques, heat-sensitive enzymes (HSE), hot air oven drying (over-flow), residual enzyme activity

## Actors' Post-Harvest Maize Handling Practices and Allied Mycoflora Epidemiology in Southwestern Ethiopia: Potential for Mycotoxin Producing Fungi Management

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Maize plays a key role in household food security in Ethiopia, but its benefit has been negated with high post-harvest losses. This study was thus initiated to assess post-harvest practices and associated fungi pathogen epidemiology along the maize supply chain in southwestern Ethiopia. The study was conducted in five purposively selected districts and a three-stage sampling procedure was employed for the selection of the target groups. In total, 342 participants from different actor groups were selected and interviewed using semi-structured questionnaire. Maize samples were collected every month from 63 randomly selected actors for mycological analysis until six months of storage were reached. Survey results showed 10 post-harvest activities practised by actors. Post-harvest loss estimated to 31 % and loss during storage was identified as a critical point. Comparing all biological agents, loss due to fungal pathogens in the store ranked on top. Moisture content at loading stage could not increase the shelf life of the commodity. Germination test showed a significant ( $p < 0.01$ ) decrease as storage duration increased. But, mould incidences on cobs and kernels significantly ( $p < 0.05$ ) increased as storage duration increased. In total, seven fungal genera were isolated, characterised and identified, of which *Fusarium*, *Penicillium* and *Aspergillus* spp. were the predominant once. *Penicillium* and *Aspergillus* spp. showed a positive increment which requires a priority in attention for the control of those well-known mycotoxin producing fungi. However, *Fusarium* spp., decline as storage duration increases. Most of the post-harvest practices are not effective in reducing post-harvest losses. Especially, farmers' traditional storage structures can be influenced by external climatic conditions and are liable for the development of mould during the rainy season. This research, therefore, highlights the need to design/develop or modify existing storage technologies that reduce post-harvest loss due to fungal pathogens. Furthermore, post-harvest drying to obtain optimum moisture content is also crucial to reduce losses.

**Keywords:** Mould, post-harvest loss, post-harvest management, storage fungi, stored maize

# Food, nutrition and gender aspects at the HH level

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## The Importance of Informal Seed Systems for Food and Nutrition Security in Kenya and Uganda

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Smallholders are vital for food and nutrition security in East Africa. Seeds, particularly uncertified seeds, accessible via informal seed systems (ISS), traditional social networks and family relations, are important for local food production. ISS in particular, are robust, and can supply seeds even during crisis periods, in contrast to formal seed systems with certified seeds. Due to a severe drought in 2016, agricultural production was heavily stressed in Teso (Kenya) and Kapchorwa (Uganda), study sites of the HealthyLAND project (HLP). Both areas differ in topography (Kapchorwa being on Mt. Elgon, whereas Teso is relatively flat), affecting farmers' access to seeds. Therefore, Kapchorwan villages appear to have a higher remoteness than those in Teso. This study aims to compare the importance of ISS for smallholders' crop production and food security, under varying degrees of remoteness.

Four HLP villages in each study site were randomly selected. A second random sampling within the selected villages was conducted to identify focus group discussion (FGD) participants from HLP households. Two gender-separated FGDs were conducted per village. Participants of FDGs were asked for their seed sources and recipient. Additionally, guided interviews on seed sources and recipients were conducted with persons named during the FGDs (41 women; 16 men). Data was analysed using the nutritional sciences concept 'dietary diversity', by classifying seed into food groups (FGs). The number of crops per FG and the number of FGs a person had accessed seeds for was evaluated.

In both regions, the bulk of seeds came from ISS. Gender showed no effect on the number of species per FG, being generally small ( $n=1-2$ ). Kapchorwan Interviewees had seeds for  $n=3-5$  FGs and FGD- participants for  $n=2-5$  FGs. In Teso, interviewees and FGD-participants had seed for an equal number of FGs ( $n=3-4$ ). Proximity and access to trading centres had an influence on the accessibility of seed in both countries. In remote villages, either less seed was transferred or more actors were involved in equal numbers of seed transactions. Following drought, ISS were essential for seed provision. These can be fostered by establishing communal seed banks to secure smallholders' food and nutrition security.

**Keywords:** Access to seeds, dietary diversification, East Africa, food groups, seed systems

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## The Impact of Drought Tolerant Maize Varieties Adoption on Household Productivity, Food and Nutritional Security in Benin

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In the context of climate change, some climate-smart innovation like drought tolerant maize (DTM) varieties packages were disseminated on all the heard of Benin's territory, to increase productivity, yield, income, food security, nutritional status, and poverty. This paper examines the impact of DTM varieties adoption on productivity, household food security and nutritional status, using country-wide cross-sectional data of about 518 maize farming households in Benin. We used respectively per capita expenditure, food per capita expenditure, households dietary diversity score (HDDS), household food consumption score (SCA), household food insecurity access scale (HFIAS) as outcome indicators of food security and nutritional status and grain yield of maize as productivity outcome indicator. To identify causal effects of DTM varieties adoption on productivity, food security and nutritional status, three instrumentals variables were used. Significant differences in socio-economic and demographic characteristics between adopters and non-adopters of DTM varieties were found. To control such differences and to allow a causal interpretation of the real effect of DTM varieties adoption, we have estimated the average treatment effect (ATE). At the end, our analyses have indicated that adoption of DTM varieties adoption significantly increased household food security by 12 percentage points. This helps severely food insecure households to achieve acceptable food security status by enabling them to acquire cereals and tubers, pulses, vegetables, and fruits on a daily basis. There was no significant impact of DTM varieties adoption on productivity. Our findings point out that DTM varieties can play an essential role in fighting against food insecurity in Benin.

**Keywords:** Adoption, Benin, drought tolerant maize, food security, nutritional status

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## **African Gender Yield Gaps: Things We Should and Shouldn't Change and the Evidence to Differentiate**

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While women comprise 30–80 % of the agricultural labour force in sub-Saharan Africa (SSA), their yields are typically 20–30 % less than men's, due predominately to lower resource allocation. Given that many countries in SSA are also facing food shortages, closing this gap by increasing women's yields has significant ramifications. One approach to improving women's production, thereby increasing food availability and possibly reducing global food insecurity, is encouraging the adoption of improved seed varieties.

Through a critical review of the literature discussing the extent and causes of gender yield gaps in agriculture, we argue that in order to accomplish this, not only will seeds need to be appropriate to women's needs, but women's non-farm commitments and time demands should also be addressed. The latter is especially relevant when considering evidence that farmers' efforts might be the primary determinant of observed yield differences rather than improved seeds alone. Indeed, a randomised control trial by Bulte et al. (2014) attribute the main yield difference between local and modern varieties to farmers' knowledge of growing modern varieties, which leads to changes in behaviour consistent with expectations of improved outcomes.

Applying a gendered lens to these results, female farmers' domestic responsibilities and agricultural and economic outcomes are intertwined through the relative efforts they can dedicate to each task. A woman's ability to cultivate a plot of land may be impeded by the trade-offs required, particularly in terms of available time and energy. Furthermore, if women redistribute their efforts from other duties or livelihood strategies, this will have latent consequences that should be considered. Rather than targeting women with approaches to adoption similar to the one used for men, tailoring technologies to account for women's responsibilities is more likely to improve output, without overburdening them. This may not lead to equal productivity but might be the optimal outcome given the trade-offs.

**Keywords:** Extension approaches, food security, gender, labour trade-offs, yield gaps

## Challenges and Opportunities for Food Security and Food Sovereignty in the Final Peace Agreement between the Colombian National Government and the FARC-EP Guerrilla

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After more than five decades of internal conflict, the Colombian government and FARC-EP guerrilla signed a Peace Agreement in 2016. The focus of such agreement was the Integral Rural Reform (IRR) that builds the bases to solve the agrarian question in the country. The objective of the current proposal is to explore the challenges and opportunities of the IRR in the scope of the Colombian food security and food sovereignty. Through a qualitative approach, using indepth interviews with different stakeholder which included Colombian government advisers in the peace negotiation and FARC-EP leaders, the most relevant topics related to the contradictions between the parties were identified and analysed. One of the main findings was the extreme disparity between the concepts of both sides. On one side, the FARC-EP tried to include the concept of food sovereignty as the base of the public policy of rural development, while the Colombian government was claiming for the food security as the way to supply food for Colombian people. The strategy to solve the divergences was the Right to Food, which includes elements of both positions. Related to food security the objective was the improvement of food availability, access, and consumption, especially in rural communities. Regarding food sovereignty, the goal was to include participation strategies in the different phases of agro-food public policies. The challenges for the IRR are notable. These challenges include the Colombian institutional weakness and the decrease of national budgets mainly due to the international oil prices. Nevertheless, the most critical threat to the agreement is the change of government in the current year (2018), because of the opposition the radical right-wing party, which is leading the presidential election. IRR becomes a new attempt to solve the historical debt of the Colombian State with its peasantry. In this sense, the participation of the civil society is decisive to succeed the Peace Agreement, as well as to promote the rural communities efforts to decide on their development process.

**Keywords:** Colombian National Government, FARC-EP guerrilla, food security, food sovereignty, integral rural reform, peace agreement, right to food

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## **Smallholders' Perception of and Responses to Climate Change – Evidence from Tanzania**

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Farmers' subjective perceptions of climatic change are not always in line with historic climate evidence. Validated or not: There is a strong link between farmers' perception and their behaviour. Therefore, local adaptation choices remain controversial, as they are based on these perceptions. The paper therefore tries to answer the following questions: First, what are farmers' perceptions on climate change, especially with regard to rainfall and temperature? Second, do these perceptions correlate with evidence from climatic data? Third, how do farmers respond and what are the factors determining the choice of adaptation? The analysis is based on primary household survey data from a sample of 900 farmers in rural Tanzania and secondary data from local meteorological stations in the study regions of Dodoma and Morogoro. While farmers' perception of a rising average temperature over time are generally confirmed by evidence from historic climate data, this cannot be said about rainfall. In the farmers' perception, rainfall volume over the year decreased, but climate data rather indicates a decrease in the number of rainy days and simultaneously an increase in the intensity of rain on these rainy days. This change in rainfall pattern can also affect the farmer negatively, however we do find that the link between farmers' perception and their behaviour is not very strong. Although farmers perceive climate change to happen and to affect them, still some farmers choose to do nothing or only respond in an evasive way, i.e. in a way that will not protect them from future damage. Only a small share chose investment-intensive strategies such as irrigation systems. Factors on the decision to adapt to climate change are chosen based on the framework of Grothmann and Patt and analysed using logistic regressions. Results indicate that not only education or access to credit play a role, relating to the farmers' ability to adapt towards climatic changes. This analysis also identifies factors for the intention to adapt by including personality traits, such as extraversion and conscientiousness, and the experience of monetary loss because of climatic shocks. This approach gives a more complete picture of the farmers' adaptation choices.

**Keywords:** Climate change adaptation, personality traits, Tanzania

## Homegarden Food Production and Diet Composition in Rural Limpopo Province, South Africa

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In Limpopo province, South Africa, food insecurity remains a constant struggle for the rural population and many people suffer from vitamin A, iron and zinc deficiency caused by unbalanced diets. It has been hypothesised that homegarden systems show a high degree of resilience in times of climatic variability and enhance food security by increasing the availability of micro-nutrient rich foods. Currently, little is known about the role that homegardens play with regard to diet composition in rural Limpopo. Therefore, the objectives of this study were to analyse the food security situation in the study area as well as to quantify the contribution of homegardens to dietary diversity. Semi-structured interviews were conducted in 130 households of six representative rural villages located within the same climatic region. Each interview started with filling in a previously tested questionnaire and ended with an assessment of the homegarden, whereby the plant species diversity was captured. A total of six food security indicators with different recall periods were calculated. The household food insecurity access scale (HFIAS) categorised 41 % of the surveyed households as severely food insecure. In contrast to the food accessibility situation, the quality of diets was found to be adequate. As the food consumption score (FCS) analysis revealed, 87 % of the households showed acceptable dietary patterns with regard to consumed food groups. Homegardens were a considerable source for dark green leafy vegetables (67 % of households obtained those from their garden), as well as for fruits, nuts and legumes (36 %, 35 % and 33 % respectively). On average, homegarden production accounted for 15 % of the households' dietary diversity. Among the identified fruits and vegetables, there was a variety of food plants known for their superior nutritional content like *moringa* (*Moringa oleifera* Lam.), jute mallow (*Corchorus olitorius* L.) or brown ivory (*Berchemia discolor* (Klotzsch) Hemsl.). Households who obtained fruits from their homegarden showed a significantly higher consumption frequency (5.2 days per week) than households who acquired them from elsewhere (3.6 days per week). This study demonstrates the positive effect of homegardening on healthy diets for the rural poor in Limpopo Province.

**Keywords:** Dietary diversity, food security, homegarden, nutrition

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## **The Phenomenon of Seasonal Hunger among Coffee Farmers: A Case-Study on Smallholders in Caranavi, Bolivia**

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Seasonal hunger is a chronic and persistent condition that significantly affects the most vulnerable in rural society. Infants and children are particularly susceptible to vicious diseases, such as diarrhea and malaria, in addition to growth and cognitive development complications resulting from poor nutrition and weakened immune systems. Additionally, adults confront significant weight-loss and suffer from anemia and diminished immune function, which is especially detrimental to women's fertility. Coffee producing regions universally struggle with many of the consequences of seasonal hunger. However, the basis for seasonal hunger among coffee households is not fully understood. The coffee-producing region of Caranavi, Bolivia is characterised by comparable poverty and hunger related health conditions, offering a compelling case to study this phenomenon. The aim of this thesis project is to raise awareness to this problem by examining the magnitude of seasonal hunger and key contributing livelihood factors among smallholder coffee producers in Caranavi. Principally, it seeks to identify the opportunities that enhance living standards and support livelihood sustainability by:

- (1) examining the phenomenon of seasonal hunger, its causal factors, and determining who are the most vulnerable. This objective focuses particularly on intra-household, gender and age related aspects of the phenomenon.
- (2) identifying and prioritising coping strategies to help households reduce their vulnerability to seasonal hunger and maximise their resilience.

A case-study approach is employed for this project, in combination with a mixed methods strategy to examine causes and responses to seasonal hunger. Data are gathered through: Participant observation, household survey, seasonal calendar, photovoice focus group and key-informant interviews. Regression models based on livelihood factors to predict seasonal hunger, and to formulate a farm typology analysis for the purpose of farm-targeted intervention are conducted. The results from this research will provide an understanding of the factors and conditions that allow for seasonal hunger to persist, in order to identify viable opportunities that offer relief and strengthen resilience to the cycle of poverty and hunger. This research project seeks to examine and recommend solutions to the problem of food insecurity manifested through seasonal hunger within a rural community inflicted with poverty and limited access to food.

**Keywords:** Coffee, gender, poverty, seasonal hunger, smallholders

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## Contextual Factors of Food Insecurity in Rural Communities in Tanzania: Developing Social Learning for Community-Based Innovations

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In Tanzania 40 % of children younger than five years of age stunted. This situation is even more severe in remote rural areas. To safeguard food and nutrition security and sustainable development, projects put a strong emphasis on tailored nutritional education programmes. Education programs are more effective when local knowledge and problem perceptions are integrated into social learning processes. However, it is not clear which pedagogical process should be included to consider contextual factors in nutrition education programs in the context of sustainable development. This work aims to understand the contextual factors of food and nutrition insecurity, targeting community problem perceptions in remote rural villages in Tanzania, Africa. The methodological approach was based on three steps: exploratory expeditions; household survey (n 663); and pedagogical workshops (n 270) applied in four study cases. Our findings show that, despite the influence of biophysical environmental conditions (lack of infrastructure, and water scarcity), also interpersonal factors play a fundamental role in critical food insecurity situations (conflicts, beliefs, consumption practices). Although food insecurity was identified in all four case study sites as a significant local problem, the underlying causes and contextual factors of food insecurity differ in each one of the Tanzanian villages. Identifying local problems perception is a fundamental approximation to the reality of local population which the sustainable development projects propose to transform. The pedagogical process of codification and decodification of hunger situations are indicated as a key activity to generate nutrition education programme in the context of social learning to development projects. The findings can inform the policy planning sectors of food security in developing livelihood diversification strategies and educational tools for sustainable development.

**Keywords:** Freire pedagogy, nutrition security, sustainability

## **Development of the Project-Level Women's Empowerment in Agriculture Index (pro-WEAI)**

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Although there is growing commitment by agricultural development agencies and project implementers to women's empowerment, both as a goal in itself and as a way to improve development outcomes, there is still no clear understanding of how to include women's empowerment indicators in assessing agricultural development projects. Without such indicators, there is no way to know which types of project or project implementation strategies work to empower women and which do not. A recently available standardised survey-based tool, the women's empowerment in agriculture index (WEAI), has been widely-used to measure and understand women's empowerment and inclusion in the agricultural sector. However, the WEAI includes indicators that may not be relevant for all projects and excludes others that would be useful for monitoring project impacts. Allowing for flexibility in integrating project-specific questions into the WEAI framework will provide projects with more detailed and useful information for project design, monitoring and evaluation, while retaining both multi-dimensionality to capture indirect and unintended impacts and comparability across projects.

This paper details the adaptation and validation of a project-level WEAI (or pro-WEAI) that agricultural development projects can use to diagnose key areas of women's (and men's) disempowerment, design appropriate strategies to address deficiencies, and monitor project outcomes related to women's empowerment. The paper follows the evolution of pro-WEAI through each step of development, including: (1) how pro-WEAI differs from other versions of the WEAI; (2) the piloting of pro-WEAI by 13 agricultural development projects during the Gender, Agriculture, and Assets Project, phase 2 (GAAP2); (3)+qualitative work exploring concepts of women's empowerment in the project sites; and (4) analysis of the quantitative and qualitative data from the GAAP2 projects, including correlations of pro-WEAI with age, education, wealth and other measures of empowerment and intrahousehold patterns of empowerment. The paper concludes by discussing what we are learning from pro-WEAI and possibilities for further development of empowerment metrics.

**Keywords:** Agriculture, gender, measurement, women's empowerment

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## The Impact of Household Head's Gender on Food Security in Syria

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Food security and eradicating hunger are gaining more attention from the global community. Together with gender equity, they form a priority on the development agendas of many countries including Syria. Entering its eighth year, Syrian crisis has severely affected agricultural sector and food production, leaving what was once a “self-sufficient” food-producing nation under the threat of food insecurity. UN reports indicate a significant disproportion of females over males in active population resulting from the conflict. With little evidence on the role of household-head's gender in achieving food security, the question that arises is if female headship can successfully replace that of males? To close this gap, our main objective is to examine the effect of household-head's gender on food security.

Primary data were obtained from a 2017 survey conducted by the Syrian National Agricultural Policy Centre. Some total of 1381 households were interviewed in 12 governorates. Food security is estimated based on the World Food Programme's Food Consumption Score (FCS). To estimate gender, we used the household-head's gender to reflect the decision-making process for agricultural production and food expenditure. In our sample, 72 households were female-headed, and in 40 of them, women were the “bread-winners”. Taking the FCS threshold, only 0.6 % of households were “food-insecure”, 6.6 % were on “borderline” and 92.8 % had “acceptable” food security level. We used the OLS regression to depict the effect of headship's gender on food security status, other variables such as land size and family size were included in the model. Findings suggest that being a female-headed household will decrease the FCS ( $p < 0.05$ ), other factors showed no or little significant effect.

The analysis provides interesting results regarding the effect of gender on food security. They show, that only limited number of households are female-headed. Furthermore, they reveal that female-headed households are more food secure. The results provide first evidence, that there is a potential, not yet fully used, of female as farms-heads for increasing food security in Syria. In future research, reasons for low share of women as households' head should be further investigated to understand the problem more in-depth.

**Keywords:** Agriculture, food security, gender, household head, Syria

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## Mapping of Resources and Potential Development for Food-Secure Region in East Seram, Maluku Province

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East Seram Maluku Province is classified as the 2<sup>nd</sup> priority by the World Food Programme (WFP), a highly vulnerable region that should be improved. The aim of this programme was to develop Agro Sector Potential map of current condition, problems, threats, potentials, and strategic policies to develop food security in this area. The programme was focused in Bula district, East Seram, Maluku Province, through: 1) literature study; 2) identification and mapping of natural resources; 3) Focus Group Discussion; 4) field work and data collection; 5) data analysis; 6) development of program; 7) workshop. The results of this programme are a) characteristics of food insecurity (1) villages without connecting road, (2) high prevalence of underweight among children, and (3) ratio of normative consumption per capita to net cereal production. The livestock were still raised traditionally on natural pastures; b) Population potentials in increasing food security stated that members of productive age can fill the job opportunities, c) Program of food security improvement stated that the two target villages, Jembatan Basah and Rukun Jaya, have not yet developed a Village-Owned Enterprise. The main problem is due to the limited human resources capable of managing it; and d) The calculation Analysis of intervention to food insecurity indicator shows that the projected achievement of the implementation of food security programme for 5 years was able to reduce food insecurity priority of East Seram District from priority 2 (prone) with composite score of 113.34 to priority 4 with composite score of 72.98. Moreover, the ideal strategy to reduce food insecurity is to build a human-centered community based on a well-targeted and sustainable insight of local resource management referring to potential village maps as references for effective planning and efficient programs designed by the government.

**Keywords:** Food-insecurity, food-security, livestock, mapping

## **Gender Perspectives on Food Security in Sarawak, Malaysia: A Case Study of the Outcomes of Migration on Agriculture**

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This study departs from a case study of an Iban village, Munggu Sawa in Sarawak, Malaysia. It seeks to uncover the outcomes of agriculture and migration as livelihood strategies in relation to food security, and how these outcomes are influenced by gender. The study was conducted during twelve days interdisciplinary research and mixed social sciences and natural sciences research methods were employed. Our study shows that migration is adopted as a livelihood strategy by children from every household in Munggu Sawa (MS), and that this is case for both men and women. Nonetheless the reasons for adopting this strategy are different for men and women; men predominantly migrate for work whilst women migrate primarily for relationships. Outward-migration and the subsequent decrease of young workforce is resulting in tendencies towards de-agrarianisation and thus behaviour that is described in literature as being symptomatic of the erosion of agricultural practices. Thus, the role of agriculture is assessed, however in this case, agriculture is still essential for achieving food security as it provides both subsistence and cash income. Remittances are also significant to the livelihoods of several households. Another impact of migration is that elderly, and predominantly female villagers have been left behind in MS. These women are coping with their vulnerable position through using their family networks in order to receive remittances. However, their distribution is unequal. Lastly, crops are managed by both men and women, although the recently introduced oil palm may influence this, as its cultivation is male dominated and that female weaving practices represent an unrealised potential for income provision, due to limited market access.

**Keywords:** Adat, agriculture, coping-strategies, food security, Iban, livelihoods, rural-urban migration, Sarawak



## Household Assets and Food Access Security in and around Medium-Sized Towns in Tanzania

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It is widely established that household food insecurity is caused by lack of necessary assets to acquire food. The contribution of these assets varies from one household to another and from location to location depending on the options available, and the household's wealth status. The questions which arise are thus: (1) to what extent household asset ownership varies in places regarded as urban, peri-urban and rural? (2) Which of the household assets influence food access security in such areas? A cross-sectional research design was employed whereby a stratified random sample of 279 households was drawn along the urban-rural continuum in Morogoro and Iringa, Tanzania. Household food access security was assessed using the household food insecurity access scale (HFIAS) whereas chi-square test was used to test relationship between resource ownership and the location of the household along the continuum. Binary logistic regression was performed to determine the influence of household asset ownership on its food access security. It was found that asset ownership varied significantly among urban, peri-urban and rural households. Additionally, it was revealed that household food access security improved as household head's education ( $\beta = 0.213$ ;  $p \leq 0.01$ ) and number of household members earning income ( $\beta = 1.115$ ;  $p \leq 0.05$ ) increased. On the other hand, food access security worsened as household size ( $\beta = -0.408$ ;  $p \leq 0.05$ ), the proportion of consumption expenditure on food ( $\beta = -0.151$ ;  $p \leq 0.001$ ), and reliance on donations ( $\beta = -3.770$ ;  $p \leq 0.01$ ) increased. It is concluded that households asset ownership vary greatly among urban, peri-urban and rural households. Also, the influence of household's assets on its food access security varies along the urban-rural continuum. Therefore, households along the urban-rural continuum should strive to own mostly assets that enable them to produce or purchase enough food.

**Keywords:** Asset ownership, food access security, household, peri-urban and rural areas, urban

## Behaviour in Agricultural Practices and Feeling of Low Food Security in Guatemala

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This study examines the behavioural differences in agricultural practices of the households who worry about their food security situation and those who do not. The analysis is based on the household survey data from 2016 of more than 2,000 bean farmers in Guatemala. The survey questions about household behaviour in agricultural practices include risk and ambiguity aversion on adopting a new technology, and frequency in sharing agricultural information and inputs with friends or neighbours. On food security, households were asked whether they were ever worried in the three months before the survey that the food in the household would run out. They were then asked whether the food actually ran out during that three-month period. Based on their responses to these two questions, the households are grouped into three categories: (1) not worried and food ran out (no to the first question and yes to the second); (2) not worried and food did not run out or worried and food ran out (no to both questions or yes to both questions); (3) worried but food did not run out (yes to the first question and no to the second). We use ANOVA to analyse whether responses to the behavioural questions are different among the three groups of households. Results show that both the “not worried” and “worried” groups share agricultural information less frequently than the reference group (group 2). On the other hand, there is no significant difference in seed and inputs sharing among the three groups of households. These results also hold after using a multinomial logit regression analysis to control for household characteristics, such as age, education, household size, wealth, land size, and household location. Even though direction of causality cannot be established through this study, conceptually it is likely that sharing information more frequently with the other households leads to more accurate predictions about own food security situation because the analysis outcome is true for both the “worried” and “not worried” groups and also for households with high and low food security. Therefore, information sharing could be emphasised more in future extension messages to the households.

**Keywords:** Behaviour, food security, Guatemala, information sharing

## Food Security and Production Shocks: Panel Data Analysis among Indigenous Vegetable Producers in Kenya

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Acquisition of food and provision of adequate nutrition are among the basic human endeavours. Smallholder farmers in developing countries respond to conditions of food scarcity using various ‘consumption-coping’ strategies. For instance by changing consumption habits when they anticipate food scarcity problem. They could use short-term, easily reversible strategies such as eating less preferred food, or reducing portion size or long-term, less reversible strategies such as selling productive assets to buy food. Even though the long-term livelihood coping strategies are important, research has shown that short-term consumption coping strategies are vital and accurate indicators of acute food security. At the same time households in developing countries face various unexpected negative events i.e. shocks simultaneously such as drought, crop failure and unexpected heavy rains. The occurrence of these unexpected events aggravates the existing problem of food insecurity. However, limited research is conducted to analyse the link between occurrence of shocks and households’ use of short-term ‘consumption-coping’ strategies. Therefore, this research seeks to analyse the effect of shocks on households’ use of ‘consumption-coping’ strategies using panel data from indigenous vegetable producers in Kenya. We calculate coping strategy index (CSI) following Maxwell (2008) and use households reporting of shock occurrences in the 12 months prior to survey. The preliminary result from panel data analysis shows a clear and significant link between occurrence of shocks and use of consumption based coping strategies. This provides empirical evidence that shocks indeed influence acute food security situation of households and calls for informed policy actions to prevent the occurrence of these shocks to minimise their effect on food security.

**Keywords:** Food security, indigenous vegetables, Kenya, panel data, shocks

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## **Local Adaptation Mechanisms to Address Climate Led Food Insecurity in Far-Western Nepal: The Case of Badimalika Municipality**

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The study was carried out to understand the food security situation and coping mechanisms due to an effect of climate change on food security of Badimalika Municipality of Bajura district in the far-western region; an acute food deficit district of Nepal. Literature review, household questionnaire survey to document primary data, stakeholders' consultation with field observations were the principle methods applied to explore the possible adaptation measures for securing food and livelihood of people. The research revealed that the district is food insecure for at least six to nine months of a year which is worsened by climate induced natural disasters: flood, landslides and drought. Sudden and unpredictable precipitation both in winter and monsoon has distorted the productions over the years. Considerable proportions of grazing land and forested area have been converted into farmland especially in the highlands. Migrating working class manpower to India to seek livelihoods is a menace to development in the place while seasonal migration in and outside the country is an interesting adaptive mechanism in the district. Drought resistant crop varieties such as finger millet (*Elusine coracana*), foxtail millet (*Setaria italic*), wheat (*Triticum aestivum*), and amaranth (*Amaranthus* sp.) are highly potential cereal crops that need to be promoted. Some humanitarian agencies with the support of the government of Nepal have been playing an important role in reducing the impact of food deficiency in the region. National food corporation district office supplies the deficit quantity of food to the people. The government needs to make agriculture the highest priority with increased investment schemes to avert the looming food crisis with emphasis to further research based activities through understanding the impact of climate change on specific crops and respective technological interventions, incorporating local adaptation mechanisms for disasters and climate change. Slow-forming terraces, conservation tillage, crop diversification, selection and promotion of drought-resistant varieties of crops, ecological pest management, seed and grain storages etc. are some technological innovations to be considered for enhancing food security.

**Keywords:** Adaptation, climate change, food security, interventions, migration



## Socio-economics

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# Adoption versus dis-adoption of innovations

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## Using a Smartphone App to Collect Data on Smallholder Farming Systems in Zambia

THOMAS DAUM<sup>1</sup>, REGINA BIRNER<sup>1</sup>, HANNES BUCHWALD<sup>2</sup>, ANSGAR GERLICHER<sup>2</sup>

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The collection of data on time use is very challenging in smallholder agriculture, considering the diversity of farm activities and the fact that they are subject to an intra-household division of labour. Yet, accurate time use data are important, for example, to measure labour productivity. The standard approach to collect time use data are recall questions in farm household surveys. There is evidence that this approach involves considerable inaccuracies. For example, a recent study has shown that smallholder farmers in Tanzania largely overestimate their working time when asked through post-harvest household surveys as compared to when asked on a weekly basis. Recall biases can be reduced by increasing the frequency of data collection, but this involves major costs. The use of smartphone apps can considerably reduce these costs and increase the accuracy of data collection, because an app can allow farm household members to enter data in real time. Yet, such an app needs to be simple to use, considering the high levels of illiteracy in rural areas. To meet this challenge, we developed a picture-based smartphone app called “Time Tracker.” After intensive pre-testing, we applied the app with 62 households in rural Zambia. In each household, the head of the household, one spouse and one child received a smartphone for three days to record their time use and nutrition. This application was repeated five times during the farming season to capture seasonality. Altogether, approximately 2790 days of data were collected. We discuss the experience of using this app for analysing the effects of agricultural mechanisation on intra-household time use and on food consumption. In addition, we compare the time use data recorded with the app with data collected through 24-hours-recall-questions. Based on this experience, we discuss the potentials of using smartphone apps to collect socioeconomic and agronomic data on smallholder-farming systems in real time. We also suggest ways to combine data recorded by respondents through the “Time Tracker” app with built-in sensors of smartphones and external sensors, which will allow agricultural economists to use fascinating new ways of data collection in the digital age.

**Keywords:** Gender, labour division, labour productivity, mechanisation, nutrition, smallholder farming, smartphone app, time use, Zambia

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## The Impact of Upgrading Strategies on Income Inequality in Rural Communities: Evidence from Tanzania

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Current agricultural research aims to increase the income and food security level of rural households in developing countries by implementing upgrading strategies. However, further effects e.g. on inequality is barely performed. It can be assumed that improvements in household welfare may result in income inequality rising in a region with implementation research. Most of the existing literature is based on region- or countrywide data; only fewer empirical studies exist at community levels. The study examines a) the effect of income sources on income inequality and b) the effect of implemented upgrading strategies on inequality. We use a panel dataset including 820 households from four treatment and two control villages located in Dodoma and Morogoro regions in Tanzania conducted in 2013 and 2015 for the purpose of accompanying research of an implementation project along local agricultural value chain (e.g. production, processing and marketing). The study uses the decomposition of income inequality to detect different types of income sources and their contribution to income distribution within rural villages. The difference-in-difference (DID) method and propensity score matching (PSM) is applied to estimate the impact of implemented pro-poor strategies on the source of income inequality in the study area. First findings from the decomposition of income inequality show that positive welfare effects from self-employment activities and livestock production increase the level of income inequality within the treated households while income from agricultural activities, off-farm activities, remittances and public transfer show equalising effects on the income distribution. The overall income level of the treated households (n=486) has a significant higher increase compared to the control households (n=334), the treatment households indicate a lower decline in income inequality compared to the control households. The DID combined with the PSM will provide further insights on the determinants of these results.

**Keywords:** Agricultural value chain, income inequality, rural communities, Tanzania, welfare

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## Factors Influencing Implementation of Buffer Strips by Smallholder Farmers in Teso, Rural Kenya

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Buffer strips are an agro-ecological practice that has potential to simultaneously tackle the problems of decreased soil fertility and to improve food security and dietary diversity. Nevertheless smallholder farmers are often reluctant to adopt this technique. The factors influencing implementation of buffer strips by the farmers in Teso, rural Kenya, were assessed by using a sequential-exploratory study design.

Focus group discussions (FGDs) with 30 farmers were used to gain knowledge on farmers' knowledge, attitude, practices and perceptions on buffer strips. The results were used to develop a household survey which was carried out among 257 farmers who had a kitchen garden. The aim was to capture the farmer profile, details about kitchen gardening practices and the extent and manner of buffer strip implementation. Only 55 % of the farmers in Teso had heard about buffer strips prior to the survey. These farmers (n=142) were able to define the main drivers of and barriers to the adoption of this practice. Protection from animals (86 %), food production (18 %) and improved soil fertility (15 %) were named among the most important drivers which also gained respectful rankings within FGDs. Similar factors were identified as barriers: providing shade, attraction to animals and reduced soil fertility for the main crop – ranked 1–3. These findings indicate that the farmers were especially focused on the direct, visible and short-term benefits.

Generally missing know-how was mentioned as a limiting factor by the survey participants. Other hindering factors were availability of arable land, land tenure, cost of seeds and labour constraints.

Most of the farmers had started implementing the buffer strips only shortly before the survey. Thus, they had not been able to observe the long-term effects like improved soil fertility yet. However, 'information brokers' might have put the emphasis on short-termed objectives and biased the farmers, accordingly. The development of an information system for farmers which would support the adoption of valuable practices such as buffer strips is needed. Communication skills are required on how to motivate farmers to also consider long term effects of their farm activities.

**Keywords:** Buffer strip adoption, dietary diversity, information transfer, soil fertility

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## **Agricultural Technology Disadoption: Why Rural Farmers Abandon Improved Rice Varieties**

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The New Rice for Africa (NERICA) is an agricultural technology innovation comprised of high yielding rice varieties introduced to increase food security and reduce poverty in Nigeria and 28 other sub-Saharan African (SSA) countries. These NERICA varieties have performed below expectation, with more than 50 % adopters abandoning them after only two years of cultivation in Uganda and Benin Republic. Despite over 60 improved varieties released between 1960–2013, Nigeria is still the largest rice importer in SSA and we have found no previous study investigating why Nigerian rural farmers disadopt improved rice varieties.

Quantitative data analysis confirm qualitative findings and three reasons are adduced for high rates of NERICA disadoption. Firstly, up to 100 % government subsidy for certified seeds, chemicals and inorganic fertilisers lowered entry costs during seed dissemination project; but the withdrawal of these subsidies decreased continued NERICA profitability. Secondly, nationwide dissemination of NERICA in locations with low and unreliable rainfall resulted in high yield losses due to drought. Thirdly, farmers updated their information about NERICA. Without government subsidies, NERICAs were labour-intensive and more susceptible to bird pest damages resulting in higher opportunity costs. Combined, these three reasons reduced the relative advantage of NERICA over other existing rice varieties.

Furthermore, while agronomic traits (e.g. yield and tillering ability) of improved varieties determine yield, consumption traits (e.g. whiteness, taste and cooking ability) determine marketability and relative profitability which influence farmers' decision to continue adoption in subsequent season(s).

We conclude that to reduce disadoption rates of future improved varieties and enhance agricultural sustainability, rice breeders should prioritise varieties with desirable consumption traits. Dissemination of improved varieties should be guided by ecological suitability and not political sentiments for increased impact. Furthermore, access to credit, effective extension services and stable policy environment that facilitate availability and affordability of complementary inputs should also be enhanced.

**Keywords:** Disadoption, improved rice variety, NERICA, Nigeria, sub-Saharan Africa, technology adoption

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## Training on Participatory Spatial Information Management and Communication

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Land grabbing and disputes over land ownership are serious issues that affect livelihood of farm families, environment, economy, social welfare and human rights, especially in developing countries. Farmers often do not know the value of their natural resources and the exact geographical data of their land. Documentation may not be in order or does not exist at all, and farmers may not be able to defend their land against political and economic interests. In many countries, indigenous and other marginalised people are not well-engaged in effective policy dialogue on issues related to the territories they use, manage and occupy. The participatory creation of maps began in the late 1980s. At that time, development practitioners were inclined to use participatory rural appraisal (PRA) methods. The international conference on mapping for change in 2005 was a landmark event where 154 practitioners from 45 countries convened to discuss state of the art participatory spatial information management and communication and its potential, constraints, opportunities and threats. In response, the EU-ACP Technical Centre for Agricultural and Rural Cooperation (CTA) conceived a training kit on participatory geographical information systems (PGIS) in partnership with the International Fund for Agricultural Development (IFAD). The English and Spanish versions of the training kit were produced over a period of two and a half years (2008–2010) with the contributions of more than 40 international specialists representing civil society and academic and development agencies from across the globe.

Use of the training kit by technology intermediaries, researchers, government officials and development agencies is expected to ensure that indigenous and marginalised communities participate in documenting, representing and communicating their knowledge, while taking control over the processes involved. The training kit, available online and on DVD, offers building blocks from which trainers can design and build their own workshops according to the needs of their audiences. The training kit includes 15 modules, each of which is comprised of units. A module is a comprehensive collection of training materials related to a specific topic. Each unit includes a number of components. A unit is the content to be covered in a single training session.

**Keywords:** Participatory geographical information systems, training kit

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## Of Bulls and Bulbs. Using Drawing Exercises to Explore the Aspirations of Rural Zambian Youth

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During the last years, policymakers and development-practioneers focused heavily on making farming more attractive for the rural youth in Africa. To reach this goal, different actions are proposed, often emphasising the need for modern technology and information and communication technologies (ICTs). These proposed actions are mostly based on anecdotes and prior policy beliefs, but not on empirical evidence since scientists have largely neglected this topic. This paper aims to contribute to a deeper understanding of the aspirations and perceptions of young people and therefore to the formulation of policy actions that fit these aspirations. Two research methods were used to explore the aspirations and perceptions of rural youth: interviews and drawing exercises, a novel method in this context that allows for both a qualification and quantification of aspirations. The results show that the rural youth has very diverse opinions and aspirations. In contrast to the literature, young people were found to reflect carefully about the good and bad sides of farming, rural and urban life, and of foreign countries. Imagining their future farm, young people mostly envisioned increasing farm diversity, using draught animals and applying more fertilisers. Few respondents mentioned the use of modern technologies such as tractors, and none mentioned ICTs. While it is difficult to generalise our results, the findings suggest that policymakers and development-practioneers need to pay more attention to the actual aspirations of the rural youth to avoid well-intended but misguided policies. The study also highlights the potentials to use drawing exercises as reserach tools. While our analysis remained mainly qualitative, the drawings of the respondents could also be analysed and coded with scores to calculate aspiration levels. Using drawing exercises both as a qualitative and quantitative research tool would allow for the generation of valuable insights into what young people aspire, both for policymakers and as indicators of aspiration levels that are interesting for researchers.

**Keywords:** Africa, aspirations, drawing exercise, future farm, youth, youth bulge, Zambia



## Undergraduates' Perception and Attitude Towards Traditional and Complementary Medicine: A University-Based Survey in Indonesia

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Complementary and alternative medicine (CAM) have been broadly recognised in low to medium income countries and good proportion of population still rely on it. Yet, these practices vary greatly from country to country and from region to region, as they are influenced by wide range of factors such as culture, history, socioeconomic factors or personal attitudes and philosophy. However little is known about practice among students who do not have medical background. Such information from South-East Asia, where CAM is substantial part of health care tradition are missing. To be able to effectively integrate CAM into formal medical healthcare the actual patterns of CAM users need to be studied.

The research is based on combination of secondary sources study and primary data collection in form of self-administrated semi-structured 21-item questionnaire distributed in selected classes to students of Atma Jaya University of Yogyakarta (UAJY), Indonesia over a period of 4 months from December 2016 on. The questionnaire's structure followed previously published studies about attitude and perception towards CAM for better comparison and summarisation of selected topic.

Demographic information was analysed through descriptive analyses whilst Spearman's correlation test, t-Test were used to define association and relation between determinants. Significance level was set at  $p < 0.05$ .

Overall 557 questionnaires were gathered with a response rate of 96%. Mean age of respondents is 20.1 ( $\pm 1.30$ ) years old. The average number of known alternative medicine practices was 6.8 ( $\pm 3.5$ ) for females and 6.9 ( $\pm 4.1$ ) for males while the actual usage was only 2.6 ( $\pm 1.7$ ) for females and 2.3 ( $\pm 1.9$ ) for males. The more practices students use, the higher their willingness to recommend CAM to others (CI 0.137;  $p \leq 0.01$ ). However, friends' advice presented less than 1% the reason to start using CAM. Furthermore, behavioural changes in CAM information retrieval have been found.

Use of CAM practice shows similar patterns as in other studies. As students tend to continue to practice CAM and the factors influencing the decision-making process are widening. It is desirable to validate the security of available sources and formulate effective guidelines that reflect current healthcare requirements.

**Keywords:** Alternative medicine, attitude, health, perception, university

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## Exploring Meaning and Values of Urban and Peri-Urban Agriculture through an Ontological Approach

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Urban and peri-urban agriculture has been claimed by scientists as one of the most promising strategies to improve food security and nutrition in developing countries, especially benefiting the poor. However, in spite of its promising future as a strategy to improve life quality, it has still not reached substantial levels of adoption from local users as well as from policymakers. This research pursues to contribute on the understanding of the tangibles and intangibles values (i) that agriculture has for urban and peri-urban actors, and (ii) the values that agriculture has for potential urban and peri-urban citizens. A better understanding will contribute to identifying those factors that are hindering or strengthening the adoptability of this strategy across the different involved actors and why.

This research is contextualized in Ecuador, by exploring different urban and peri-urban groups separated by (i) adopters and (ii) non-adopters, showing similar levels of social vulnerability in the cities of Guayaquil, Cuenca, and Quito. Two research approaches and mixed methods are applied. For the group of adopters, an actor-network analysis (ANT) -ontological approach- is performed in order of following those human and non-human actors through the “value chain” of the farmed products. For the group of non-adopters, a constructivist approach is used in order of building the meaning of what “they do not do, or they do not have”. The main used research methods are (i) visual methods, such as eliciting photography and the combination of storytelling with individual drawing, (ii) individual interviews, and (iii) participant observation.

From a methodological perspective, the results from the “adopters” group show that the use of ANT as a methodological approach to making visible the tangible and intangible values that agricultural products have for urban and peri-urban farmers is successful. Since it makes possible to recognise the “food”, “social networking”, “self-stem”, “empowerment”, “agency”, “health”, “nutrition”, values that the farmed products can have for human actors. In the case of the “non-adopters”, the use of “anonymous adopters” and “own” photographs, and drawings elicited people to explore the potential value and meaning of the agriculture that “they do not do or do not have”.

**Keywords:** Ontological approach, peri-urban agriculture, urban agriculture

## Can Modern ICT Engage Farmers' Experiential Knowledge in Agricultural Advisory Services?

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Public agricultural extension systems in developing countries play essential roles in agricultural development. But they often face challenges, including budget restrictions, a dispersed rural population, and weak infrastructure. In response, recent years have seen growing interest in the use of modern information and communication technologies (ICT) for extension delivery. To date, many new ICT-driven agro-information services follow a rather traditional transfer-of-technology paradigm. Agricultural knowledge and skills, however, are often embedded in social processes, undergo transition, and are hard to formalise because they arise from context-specific experience.

Modern ICT might help to materialise farmers' experiential knowledge resources, which could complement technical information in more meaningful agro-advisory services. But capturing this knowledge will require extension to accommodate two-way information flows that systematically recognise farmers' contributions, rather than pure one-way dissemination of information. For this, ICT-driven information services likely bear underused potential: Many opportunities exist for recollection of users' feedback to extension messages, such as simple up- or down-voting, or recording more elaborate personal commentaries. Analyzing big data arising from users' interactions with agro-information services, including data on accessed advisory topics, timings of use, location of users, etc., may reveal patterns in agricultural knowledge use that reflect farmers' day-to-day farming experience. With appropriate methods, this experience could be exploited for social learning, evaluating the agricultural technologies currently promoted, or setting priorities for future research.

In Kenya and Tanzania, we engaged with farmers, agro-advisors, and researchers in an open-ended, participatory, iterative design process. We aimed at developing a new agro-information service that mobilises experiential knowledge through two-way communication flows. In our design prototype, farmers have access to a library of short audio messages about agricultural topics, recorded by advisors, researchers, and experienced farmers, through an automated telephone hotline. Farmers may voice-record comments and questions. Advisors may use an online platform to record answers and send automated phone calls to farmers' phones. Experiential knowledge may materialise by spatial and temporal analysis of keywords attributed to questions and harnessing farmers' comments for recording new podcasts. First insights from pilot implementations will be presented.

**Keywords:** Agricultural extension, experiential knowledge, ICT, information system design

## Information Transfer for Agricultural Innovation: Lessons Learned from an Agricultural Intervention in Teso, Rural Kenya

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Adoption and sustainability of agricultural innovations are highly dependent on information available to farmers; how it is packaged and disseminated to the end users. We have conducted a study evaluating the outcomes of an agriculture intervention related to buffer strips that was implemented within HealthyLAND project for smallholder farmers in Teso, a rural area in Kenya. This contribution presents and discusses main results and the lessons learned relevant for improvement of knowledge transfer.

The aim of the agricultural intervention was to promote dietary diversity through training of smallholder farmers on appropriate kitchen garden practices, specifically introducing vegetables and legumes as buffer strips. This intervention was supplemented by nutrition education aimed at improving diets of young farm families. Both trainings were performed by Community Health Volunteers (CHVs) who were trained by an agriculture expert and agricultural extension officers, yet on the agriculture intervention activities specified by a group of experts. Both qualitative (Focus Group Discussions) and quantitative (household survey) techniques were used to collect data to evaluate the outcomes of the agriculture intervention.

The outcomes of the agricultural intervention related specifically to buffer strips adoption within the HealthyLAND Project in Kenya were not corresponding to the expectations of the project team. Farmers were more likely to adopt the innovation if they felt being well-informed about the context and content. However, often farmers reported not being sufficiently informed about the benefits of the promoted agricultural practice. This could be attributed to the lack of agricultural experience of the CHVs but also how the training was planned and introduced to the farmers.

Thus, successful dissemination of the information is highly dependent on the qualification and experience of the one who transfers the information to the farmers. The way how the information is packaged and transferred is also crucial. The information should be simple to be understood (for farmers and trainers), complete, context specific and focused to attain the intended purpose. Universities need to offer specific training on how scientific knowledge should be better packaged for agriculture extension.

**Keywords:** Adoption of agricultural innovation, agricultural intervention, dietary diversity, information transfer

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## Food Safety Research in the Feed the Future Innovation Lab for Livestock Systems

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The livestock systems innovation lab (LSIL) is funded by the United States Agency for International Development (USAID), through a leader with associates cooperative agreement award to the University of Florida. The duration of the current award is October 1, 2015 to September 30, 2020. The objectives of the LSIL are to sustainably improve livestock productivity and marketing and animal-source food (ASF) consumption using appropriate improved technologies, capacity development, and policies, in order to improve the nutrition, health, incomes and livelihoods of vulnerable people.

LSIL is funding 22 projects in 6 countries, of which 7 are addressing food safety aspects of ASF consumption. Three focus grants (1-year duration) address safety of milk and milk products in Ethiopia, Rwanda and Nepal, and three focus projects address mycotoxins in animal feed in Ethiopia, Rwanda and Burkina Faso. One research grant (4-year duration) is fully focused on food safety and takes a broad approach to collecting evidence to inform food safety policy in Cambodia. One research grant addresses beef and dairy food safety in Ethiopia, including aspects of abattoir food safety. One research grant assesses consumer demand for milk quality and safety attributes in Rwanda. All projects have started and are generating results.

The CAGED project, funded by the Bill & Melinda Gates foundation, studies the balance between improved nutrition by smallholder chicken producers and exposure of young children to chicken droppings, specifically *Campylobacter* spp., as a risk factor for environmental enteric dysfunction.

This presentation will provide an overview of livestock systems innovation lab, with a focus on the objectives of the food safety projects as well as their initial results.

**Keywords:** Animal source foods, beef, dairy, food safety, mycotoxins, nutrition

## What Matters for the Job Performance of Field Level Advisors: A Case of Madhupur Sal Forest Bangladesh

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In the context of natural resource management, field level advisors are known as change agents and play a critical role in empowering resource users for joint learning and collective action. Their job performance is therefore important for achieving the wider objective of natural resource management. This study identified the factors that affect the performance of field level advisors in the context of organisational pluralism in Madhupur Sal forest, Bangladesh. This study uses quantitative methods and 87 field level advisors from nine organisations were selected purposively for data collection with a structured questionnaire. Four analytical categories i.e. i) governance structures, ii) organisational capacity and management, (iii) partnership and linkage, (iv) advisory methods from best-fit framework were used to outline the main factors responsible for satisfactory performance of the field level advisors. Besides descriptive analysis, binary logistic regression was employed to determine the factors that influence the satisfactory performance of the field level advisors. According to the results, organisational coordination, the existence of economic incentives for the execution of fieldwork, monitoring and evaluation of organisation on individually assigned work of field level advisor, total number of staff, in-service training, travel allowance, a reward and punishment system, computer and internet facilities for advisors, using group approach during field works, and interaction with forest researchers affect the performance of advisors in the provision of advice related to forest management. Our assessment provides a useful lesson for the existing advisory service providers to consider several factors to get better performance from their field level advisors.

**Keywords:** Bangladesh, best-fit framework pluralism, change agent, job performance, Sal Forest

## Varietal Choice and Adoption of Improved Cassava Varieties under Subjective and Objective Analyses. A Case of Malawi

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Most studies on adoption and impact of improved crop technologies in sub-Saharan Africa have relied more on farmer elicitation, crop experts and morphological descriptors for both varietal identification and estimation of the adoption status. However, these methods have been found to be less accurate identifying crop varieties and therefore leading to varietal misclassification. Although the extent of misidentification and misclassification has been established, their implications have not been examined. In this study, we examine the implication of misidentification and misclassification on varietal choice and adoption analyses. Using data from methodological experiment on cassava varietal identification and productivity measurement (CVIP 2015), the study found that factors driving adoption of improved cassava varieties significantly vary when adoption status and varietal choice are estimated through farmer reports or DNA fingerprinting. For example, farming experience, gender of the household head, taste of the varieties and access to extension services, though key determinants of adoption of improved varieties under farmer-reports, could not be considered as such under DNA fingerprinting. Instead, household's wealth index and engagement in non-farm activities were identified as key factors affecting adoption of improved cassava varieties. Further, results demonstrated that effects of farmer's level of education on adoption of improved varieties were underestimated by 4 percentage points through farmer reports. Though the same trend is observed under varietal choice, results showed that the taste of different varieties was more determinant in triggering farmers' choices and preferences towards a specific variety. It is worth mentioning as well that the explanatory power of the different econometric models used in the study, mainly probit and multinomial logit was particularly higher under objective analysis than under self-reporting. These findings therefore suggest that policy implications regarding choice and adoption of cassava varieties in sub-Saharan Africa need to be reconsidered and re-oriented for better promotion of the crop.

**Keywords:** Adoption, DNA fingerprint, farmer-reports, varietal choice

## Adoption Potential of *Gliricidia* Agroforestry Based Technologies in Dryland Areas of Dodoma Region, Tanzania

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The declining soil fertility, among others, due to the limited access and use of mineral fertilisers by smallholder farmers has been frequently cited as a major factor limiting optimal productivity of field crops in dry-land areas of sub-Saharan Africa including those of Tanzania. In response to this challenge, an extensive collaborative research undertaken by the World Agroforestry Centre and local research institutions, led the development of agroforestry based soil fertility management technologies in Dodoma region as sustainable options to assist smallholder farmers with limited access to mineral fertilisers replenish their soils through nitrogen fixation and recycling of nutrients. This study was conducted to simulate adoption potential of *Gliricidia* agroforestry based technologies in dryland areas of Kongwa and Chamwino districts in Dodoma, Tanzania. Adoption and diffusion outcome prediction tool (ADOPT) was used to simulate adoption potential of *Gliricidia* agroforestry based technologies at the community level. Presentation of the technology diffusion results used the S-shaped function of time. Other useful adoption indicators considered were degree and intensity of adoption. The adoption rate was used since it is associated with other farm decisions making tools such as cost-benefit analysis. Results reveal that 13 % of farmers currently practice agroforestry technologies on their farms for profit maximisation and risk minimisation. The adoption rate peaks have been projected to be very high in both districts. However, it would take 14 years to reach the adoption peak of 94 %. Further, results reveal that access to tree seedlings, land tenure and access to agricultural inputs are important conditions for higher adoption peak levels. Monetary benefits to be generated within twelve months by farmers practicing agroforestry technologies offset the initial investment costs. *Gliricidia* agroforestry based technologies show great potential in addressing multifaceted constraints to farmers including soil fertility, moisture and detrimental effects of climate change. Integration of *Gliricidia* agroforestry based technologies and other soil and water conservation technologies and enhancing farmers' access to input including tree seedling are recommended to enhance adoption and diffusion of *Gliricidia* agroforestry based technologies in dryland areas of Dodoma region. This in the long run will improve food security and livelihoods through increased productivity.

**Keywords:** ADOPT, agroforestry, dryland areas, food security, soil fertility



## Adoption of Improved Quinoa Varieties among Smallholder Farmers in the Peruvian Andes

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Production of quinoa has boomed tremendously in the Andes since the early 2010s. It is widely promoted as a highly nutritious food and is rapidly converting from a common staple and subsistence crop into a high-value cash crop. Quinoa production and trade entail large opportunities for Andean smallholders, such as upwards income mobility and improved food security. However, crop productivity does not reach its full potential due to quinoa's susceptibility to mildew, a plant disease that represents the largest constraint to high productivity in the Andes region. Developing mildew-tolerant varieties is thus a key priority of researchers and policy makers. In order to increase adoption rates of improved varieties among smallholders, it is crucial to take into account their specific requirements and needs *ex-ante*, before new varieties are developed and introduced. In this paper, we study farmers' preferences and willingness to pay for improved quinoa varieties in the Junin region in Peru. We use data from a choice experiment among 458 Andean smallholders and estimate generalised multinomial logit models to control for preference and scale heterogeneity. We find that farmers generally prefer improved varieties over traditional varieties, with mildew-resistance as most important crop trait. Farmers who are more experienced or who are a member of a quinoa production association are less likely to adopt an improved variety, while farmers who purchase seed from other producers are more likely to buy improved seed. Farmers who have encountered mildew before are even more willing to pay for a mildew-resistant variety, illustrating the severeness of the disease. Varieties that are characterised by larger grain sizes, higher yield levels, and a reduced maturation period are more likely to be adopted, while farmers are indifferent between medium and zero levels of saponin. A high level of saponin, on the other hand, is associated with a bitter taste and drastically decreases farmers' willingness to pay for mildew-resistant quinoa varieties.

**Keywords:** Choice experiment, generalised multinomial logit, Peru, quinoa, scale and taste heterogeneity

## **Do Indonesian Consumers Value Organic Rice? Evidence from a Willingness-to-Pay Experiment with Randomised Pricing**

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Organic agriculture can contribute to food security on several levels as it addresses social, economic and political constraints of conventional farming. Due to the benefits of organic agriculture, its integration in agricultural policy is crucial to strengthen food security and safety. To discuss shifts on the agricultural production side, the consumer side must not be neglected. Indonesia's organic sector can be divided into an export-oriented production sector and locally-oriented production sector. Currently, the awareness and level of organic food consumption in Indonesia is at a quite low level, yet local markets offer great potential especially for smallholders who do not have access to international markets.

Research can contribute to enhancing the linkage of the agricultural production side and local consumption side by providing farmers and public policy makers with important information about the current demand on the market. To analyse the linkage of agricultural producers and consumers in Indonesia, we conduct a willingness-to-pay (WTP) experiment in semi-urban areas near Yogyakarta. The revealed WTP is elicited through a variant of the Becker-DeGroot-Marschak (BDM) method which confronts participants with a real purchase decision as they are invited to submit a price bid for 1 kg of certified organic rice. In total, about 300 participants from randomly selected sectors are interviewed. Respondents are randomly assigned to treatment or control groups. There are two different treatment groups, one which is provided with information on health benefits of organic farming and one with information on environmental benefits of organic farming. The data collection is ongoing and will be completed end of April 2018. The findings will show the uptake for the current market price and alternative price levels. They will also show whether actual information on health or environmental aspects can increase the willingness to pay and how various individual characteristics correlate with the willingness to pay.

**Keywords:** Food safety, Indonesia, organic food, willingness-to-pay

## **Local Application of Integrated Water Resources Management (IWRM) in the Mosquito River Watershed with Focus on Vegetable Production**

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The capitalisation is part of a Research-Action approach and aims to produce, manage and share the knowledge and know-how acquired by the actors themselves in terms of practical methods of IWRM at the local level, focused on vegetable production at household level. As part of an integrated approach to water resources management initiated by Protos and ODRINO since 2008 in Haiti, several actors from the area have come together to plan, operate and manage water resources, water and associated resources. With this in mind, a Watershed Committee (CBVRM) was created. This structure has developed a strategic plan to coordinate the development and management of water resources within the estimated 40,000 inhabitants of the Mosquito River watershed. Since 2013, CBVRMED has selected the Matha Gap sub watershed to scale up the IWRM approach. The actions carried out are part of the Strategic Plan of the watershed of the Mosquitos River. At Mosquito this methodology was developed by the University of Liège (Belgium) in 2009 and has now served as a frame for implementation. Several actions were performed: protection of soils, reforestation, the production of vegetable crops which allows the recovery of animal and domestic waste, crop residues and the reduction of free livestock (protection of biological and mechanical structures has been put in place). This activity also contributes to improving the food security of beneficiary households and enables them to earn money to meet certain needs. Women are the main beneficiaries and producers of vegetables as part of the actions in Matha. In spite of the difficult journey (because of the altitude and the stiffness of the ramps), women produce vegetables even in the dry period by drawing water in the Mosquito River, an arduous task. They know the importance of market gardening for the survival of their families. For example, they testified that papaya is a very profitable crop. They sold papayas to send their children to school. The action-research is still on-going and more data are gathered to analyse the impact of the actions. Investigations on land use management and risk management are identified to be performed in the near future.

More information on the ongoing action-research is available on this link:

[https://www.protos.ngo/sites/default/files/publications/files/ra\\_2016-haiti\\_gire\\_locale.pdf](https://www.protos.ngo/sites/default/files/publications/files/ra_2016-haiti_gire_locale.pdf)

**Keywords:** Ecological sanitation, erosion, food security, Haiti, integrated water resource management, NGO

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## **Farmers' Baobab (*Adansonia digitata* L.) Knowledge and Utilisation Practices in Kilifi and Kitui Counties of Kenya: Implications for Designing Information and Training Interventions**

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The baobab tree has been used for centuries in different parts of Africa as a source of food and medicine and its exceptional nutritional properties are increasingly being recognised. In marginalised areas of Kenya where the tree can commonly be found, communities are yet to realise the full potential of this natural resource as a means to achieve food security and improve their living standards. A survey was therefore conducted in Kilifi and Kitui Counties of Kenya to assess community knowledge and training needs on baobab production and utilisation. Primary data was collected using predetermined questionnaires from a sample of 120 and 136 households in Kilifi and Kitui, respectively. The raw data was analysed using descriptive and inferential methods. The descriptive analyses revealed remarkable differences between both locations. While a majority of households (69.2 % in Kilifi and 87.5 % in Kitui, respectively) owned naturally occurring baobab trees on their land, the baobab pulp was used more in Kitui (80 %) compared to Kilifi (15 %) as an ingredient in food preparations. Baobab leaves were mainly used in Kitui as food (27.2 %); while >87 % of households in both areas did not use baobab oil. The majority of households (Kilifi 55%; Kitui 76 %) owned below 10 baobab trees. Yet, most of these trees were not only actively managed as only 10 % and 5 % of the households in Kilifi and Kitui respectively undertook any baobab husbandry and management activities. There was generally very limited knowledge among farmers on the various products that can be derived from baobab, and their nutritional value; all this courtesy of inadequate agricultural extension services. The inferential analyses investigated the influence of various socio-economic characteristics (e.g., tree tenure, household food security status, presence of baobab traders etc.) on the farmers' knowledge about the baobab tree and their management and utilisation practices, as well as the association between knowledge and actual practices. The study derives recommendations and priorities for tailor-made education, awareness and capacity building interventions addressing local communities in both localities and beyond to make farmers appreciate the nutritional and economic value of the baobab tree and its products.

**Keywords:** Baobab products, information needs, Kenya, marginalised areas, training needs assessment



# Markets and value chains

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## Cooperation versus Competition: Institutional Analysis of Raw Milk Marketing in Ethiopia

ZEWDIE ADANE MARIAMI<sup>1</sup>, ERNST-AUGUST NUPPENAU<sup>1</sup>, BERHANU GEBREMEDHIN<sup>2</sup>, AZAGE TEGEGNE<sup>2</sup>

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Milk is a perishable commodity. Adulteration and poor hygiene compromises quality and food safety. Understanding the implications of market structure and actors' behaviour in marketing such delicate commodity is essential. Differences in exchange arrangements and actors' abilities, initial resource positions, information endowments, and risk preferences could determine market outcomes. New institutional economics of markets stresses the importance of studying structure of specific transaction arrangements and provides frameworks for examining the implications of various constraints in determining market conduct/behaviour and performance. In this study, we examined raw milk marketing in Sululta, Lume and Ade'a districts of central Ethiopia using the new institutional economics of markets framework. Data were obtained through household survey, focus group discussions, and interviews with key informants and experts. Raw milk is the cheapest in Sululta compared to the other districts. Milk collection in Sululta is largely a monopsonistic competition among a few small private traders who lack advanced quality testing tools. Private collectors' inability to precisely detect adulteration creates bounded rationality. This encourages farmers to prefer private collectors to other rather strict buyers. Processors and cooperatives who dominate the market in Lume and Ade'a conduct more rigorous quality tests. The cooperatives in particular create hybrid governance where many suppliers are shareholders or members of primary cooperatives with responsibility to maintain quality. Consumers are also unable to identify adulteration when they get mixed milk from collectors which cannot be traced to a particular source. The bounded rationality encourages opportunism where some farmers add water and other substances to milk especially in private collections. High degree of bounded rationality and opportunism in unregulated markets drives out genuine farmers. This threatens the prospect of improving milk productivity and sectoral sustainability. Besides, the adulteration and deteriorating milk quality increases public health risk. Trust and personal relationships reduces adulteration when buyers get milk directly from local farmers although prices are rather high in such arrangement. Therefore, cooperative marketing, stricter regulations, better quality testing and direct marketing are important. This study showcases how organised marketing such as cooperatives and localised direct marketing could outperform unregulated competition in marketing delicate commodities.

**Keywords:** Bounded rationality, Ethiopia, milk marketing, new institutional economics, opportunism

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## Does Double Certification Add to the Productivity and Welfare of Smallholder Cocoa Farmers? Evidence from the Northern Peruvian Amazon

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Cocoa is mainly grown by smallholder farmers in the lowland tropics of Latin America, West Africa and Indonesia. An increasing share of the global cocoa area is certified to private standards, with Fairtrade, organic, Rainforest Alliance and UTZ being the most important standards, each covering between 2.5 and 15 % of the global cocoa area. Private standards are very important for the cocoa sector in Peru, a country that ranks ninth in global cocoa production but has the fourth largest Fairtrade cocoa area and the third largest organic cocoa area in the world. Although figures on the extent of multiple certification are lacking, it is becoming increasingly common for smallholder cocoa farmers to be double or even triple certified to different schemes. The combination of Fairtrade and organic certification is especially common in Peru and elsewhere. While there is a substantial body of literature investigating the implications of private standards for smallholder farmers, insights on the benefits of multiple certification are lacking. In this paper, we analyse the productivity, income and poverty effects of Fairtrade (FT) and Organic (Org) certification for cocoa farmers in the northern Amazon of Peru. We use cross-sectional survey data from a sample of 583 cocoa farmers in the San Martin Region, of which 288 are certified, including 130 FT and 119 FT-Org certified. We analyse the impact of single and double certification on six different outcome indicators: poverty, poverty gap, total household income, cocoa income, cocoa yield and cocoa price. We use logit, tobit, OLS estimations and propensity score matching techniques. We find that certification in general does not significantly improve yields or incomes, and organic certification is actually found to reduce cocoa yields and household income. This negative effect, however, disappears in double Fairtrade-Organic certification.

**Keywords:** Cocoa, fairtrade, organic certification, Peru, small farmers

## Identification of Bottlenecks and Opportunities for the Beef Value Chain of Córdoba, Colombia

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The cattle sector in the Colombian Caribbean region prefigures the most important economic activity at a regional level and counts with the best connections to the international market when compared to the rest of the country. However, there exist important bottlenecks that reduce the sector's competitiveness and hinder efforts for achieving a joint market vision, quality assurance systems and value chain sustainability. It is therefore necessary to understand the complexities and interconnections of the value chain through an integral value chain approach and to set the basis for the definition of potential markets and their development and a value chain action plan. The objective of this study was to identify the most relevant bottlenecks and opportunities of the beef value chain in the Colombian Córdoba Department in order to provide the necessary inputs for increasing its added value and market share. In the framework of a research agreement between CIAT and Corpoica aimed at strengthening the cattle sector in the region, we conducted semi-structured interviews and a participatory value chain workshop with the main value chain actors in 2017 using the following methodologies: Participatory analysis of market chains for small producers and ValueLinks. Together with the value chain actors, we were able to define the state of the art of the value chain and map it, review market opportunities and competitive advantages and identify the most relevant bottlenecks for each link. Among the main results, it was possible to identify three strategic axes that respond to the main structural bottlenecks of the sector: i) sustainable intensification, ii) search for differentiated markets, and iii) improvement of the articulation between direct and indirect actors, especially in technical assistance and credit services. The results of this research will be a key input for the construction of strategic plans for a sustainable development of the region's most important economic sector, seeking to increase its added value, share in the domestic market and access to high-value international markets.

**Keywords:** Beef, cattle production, market access, sustainability, value chain

## **Risks and Opportunities of Transitioning to Export Crops. The Cases of Pineapple and Avocado in Colombia**

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Over the last few years, the fruit sector in the department of Valle del Cauca, Colombia, has witnessed major transformations. The increasing international demand and the government's interest in diversifying the country's export portfolio has led several middle and large-scale farmers, large agro processing industries and other investors at the national level to venture in and promote the cultivation of "super sweet" MD2 pineapple and Hass avocado across the region. Looking for increased incomes, numerous small-scale farmers in the department have joined the trend and adopted these varieties, while many others are currently facing the decision of either switching to these export varieties or continuing cultivating more traditional species demanded by local markets and agro processing industries.

Although the opportunities offered by the new varieties in the international markets are highly attractive, currently a low percentage of harvested produce complies with export requirements. This combined with the rapid expansion of overall cultivated areas (particularly for MD2 pineapple), has caused sudden increases in supply and reductions in local prices. Faced with growing uncertainty, strong market pressures and rapid sectorial changes, smallholders in particular lack instruments to properly assess the risks and future competitiveness of the different productive alternatives and make more informed decisions. In response to this problem, our study attempts to provide farmers, other value chain representatives and decision makers with key information needed to be able to assess the ex-ante cost-benefit relationship and risks implied with the adoption of export varieties (MD2 pineapple and Hass avocado) by employing a probabilistic cost-benefit analysis using Monte Carlo simulation. Additionally, through the analysis of semi-structured interviews we present the opportunities and challenges identified by various key stakeholder groups along the two value chains.

**Keywords:** Fruit value chains, Hass avocado, MD2 pineapple, probabilistic cost-benefit analysis.

## Accessing and Granting Credit among Informal Milk Traders in Peri-Urban Nairobi

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Studies on credit schemes for small-scale entrepreneurs have documented their potential to alleviate poverty, increase savings, and improve education, food-security, nutrition, and health outcomes. Other studies find mixed impacts of credit schemes on reducing income inequality, empowering women, and reducing child labour. A growing body of evidence finds that small-scale entrepreneurs in low- and middle-income countries sell their goods to customers on credit, but their businesses struggle when customers fail to repay. In this paper we examine how male and female informal milk traders from peri-urban Nairobi access and grant credit, and how these experiences affect their businesses in a context where there are few safeguards. In 2017 we conducted 48 in-depth individual interviews, 4 key informant interviews, and 6 focus group discussions with men and women who are current or former milk traders. We find that milk traders feel they must sell their product on credit to appeal to customers. This can be advantageous when they need to rid themselves of milk before it spoils, yet they have few viable strategies to recoup costs from customers who do not repay. Failure to collect credit from customers has additional ramifications for milk traders who acquired milk on credit from suppliers informally, leading to debt default. The consequences of losing income to creditors is likely more severe for women traders, who generally have less capital to fall back on relative to men. Milk traders overall avoid taking formal loans from banks because of high interest rates. Additionally, women have greater difficulty in accessing formal loans because they lack collateral. Many traders instead join a credit savings group to access financial capital, despite some negative experiences as members. For example, group leaders have stolen money saved. In summary, individual milk traders function as both creditor and lender. These dual roles may have unintended consequences that jeopardise their livelihoods. Development organisations should identify financial services and other interventions to help small-scale entrepreneurs maintain viable businesses despite the volatility of accessing and granting credit.

**Keywords:** Credit, dairy traders, entrepreneurship, gender, loans, value chain

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## **The Impact of On-Farm / Off-Farm Diversification and Market Access on Household Food and Nutrition Security in Ethiopia**

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Despite large efforts in developing a more intensive agri-business, smallholder agriculture remains the main livelihood option for many rural households in Ethiopia. While technical innovations have been fostered and some progress can be observed, food insecurity persists in large parts of the country.

Recent literature suggests that both on-farm and off-farm diversification, as well as the access to agricultural markets are promising strategies to ensure or enhance food security of smallholder farmers. While market access and off-farm income diversification target an improvement through increased sales, on-farm diversification aims at stabilising and enriching the diversity of the subsistence diet. The household dietary diversity score is a suitable indicator frequently used by researchers, and covers different food groups being consumed. The concept of a diversity score, however, has been rarely applied to the production side in an adequate level of disaggregation, although an improved measure of production diversity could help to better measure its effect on household and nutrition security. In addition, market access is often measured as distances which is a rather imprecise measure for travel time.

Therefore, this study investigates the effect of market access (travel time), off-farm income, and on-farm production diversity, i.e. crop and livestock diversity, on household food and nutrition security. The analyses are based on socio-economic data collected in 2016 covering 400 smallholder farmers living in a 200 km radius around Hawassa town. By means of statistical tests and generalised Poisson estimations, the effects of production diversity (PDS), income diversification, and market access on the household dietary diversity score (HDDS based on 9 and 12 foodgroups) are analysed. Production diversity is expected to be positively associated with dietary diversity, yet at a diminishing rate. The effects for market access are expected to follow a similar pattern. Influence of the off-farm income share is projected to be positive as it can decrease the dependency on risky rainfall patterns especially for the smallest and most vulnerable farmers. Based on the marginal effects, it will be possible to draw appropriate policy implications regarding the importance of the three strategies.

**Keywords:** Dietary diversity, Ethiopia, income diversification, market access, production diversity

## Drivers of Price Volatility in Brazilian Pork Market, Internal and External Effects – DCC GARCH Approach

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Pork is the most consumed meat worldwide, and Brazil is one of the major producer and exporter countries. The pork market is affected by a number of factors that cause price volatility at national and international level. These price volatilities can affect many agents in the pork supply chain dramatically. Researchers over the last past years have studied food price volatility. Although the literature on food price volatility has been increasing since the food price crisis of 2008/09, there are still only a few studies, which are analysing the combination of drivers and spillovers of volatility. Existing studies mainly focus on a limited number of countries, commodity market, and spillovers along the supply chain. To understand the price dynamics and the effects of these drivers in the Brazilian pork market, the price volatility, its drivers, and spillovers are analysed in this study along the supply value chain, across the meat markets and in the context of the spatial market relationships. Since Russia is a major importer of Brazilian pork meat, the impact of two Russian trade policies (WTO accession in 2012 and meat import ban in 2014) are taken into consideration. A seasonal ARMA, univariate GARCH and EGARCH models are used to estimate the volatility development in nine different markets. Moreover, a multi-variate DCC-GARCH model is estimated to examine the dynamic price relationships between Brazilian live swine and the other components of the Brazilian pork market (e.g., input prices and substitute commodities). The results suggest that the live swine price volatility is mainly driven by domestic rather than by external factors. The price of substitute commodities (live chicken and cattle) present higher volatility correlations than the prices of input commodities (corn and soybean). The two analysed Russian trade policies had a significant short-run effect on changes of price volatility of live swine. They affected the dynamic correlations with the domestic price volatilities, too. Furthermore, market structure and possible market power might affect the price volatility transmission in Brazilian live swine, live chicken, and corn prices.

**Keywords:** Brazil, DCC-GARCH, food price volatility, market power, pork market, Russia, trade policies, volatility spillover

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## **“Green Village Hubs” and Smallholder Marketing Preference: A Discrete Choice Modelling Approach**

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Sustainable agriculture is emerging as an option to address food security and food safety. There is an increase in acreage under sustainable agriculture and a diversification of products from sustainable agriculture. Moreover, smallholder farmers involved in sustainable agriculture receive premiums and numerous ecological benefits. However, there is a disconnect in the information on sustainable agriculture among smallholders in Kenya. This has led to the emergence of innovations, such as “green village hubs” (GVH) that attempt to address this disconnect. The GVH has three components, which are related to marketing, extension and production respectively. Therefore, it is on this basis that we attempted to evaluate smallholder farmer preference for the marketing component of GVH innovations in Makueni County in Kenya. Our study used a sample of 130 smallholder farmers, who were obtained through a stratified random sampling. Consequently we conducted a household survey, where we administered pretested questionnaires. We used discrete choice modelling approach to analyse the attributes of GVH innovations that influence smallholder farmer preference in marketing.

First, we developed choice sets from three GVH innovations attributes. These attributes included expertise, interaction, diversity and application. In order to do this, we used some proxy variables including contracts (diversity), practicals (application), type of group (expertise) and feedback frequency (interaction). Furthermore we assigned levels to each of these attributes. Moreover, we used individuals specific characteristics as covariates in our analysis. Second, we performed a multinomial regression using the three GVH innovations (dependent variables) and GVH attributes alongside specific characteristics. Our results suggest that smallholder preference for marketing GVH innovations are significantly affected by contracts (0.66) \*\*, type of groups (0.2)\*, feedback frequency (0.18) \*\*, practicals (0.47)\*, education (-0.19)\* and age (0.13) \*\*.

Therefore, the policy on agriculture innovation hubs should focus on incorporating diversity in training. Moreover, these hubs should use a participatory approach with hands on practice as opposed to theory sessions. Our study can be viewed as a precursor to other studies on smallholder preferences of innovations in Kenya.

**Keywords:** Diversity, food safety, hubs, innovations, policy, sustainable

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## Actor Network Theory and *Ziziphus mauritiana*: Building the Resilience of Communities in Muzarabani District, Zimbabwe

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Viewed as a radical approach, the Actor Network Theory (ANT) has been used extensively in scholarly works to understand the interactions and connections between human and non-human entities to bring about the formation of a new entity. The key argument with ANT revolves around the assumption that these connections tend to lead to the creation of new entities that do not necessarily practice the sum of characteristics of the original constituent entities. With this background, this paper focuses on how ANT and *Ziziphus mauritiana*, a tropical fruit tree species belonging to the family Rhamnaceae can be used to build the adaptive resilience of poor rural households in Muzarabani District against the impacts of climate change-induced risks and hazards. The paper is based on a study that used the qualitative methodology. Using both secondary and primary data collected in Muzarabani District, it is argued in the paper that beyond the ordinary outlook of *Ziziphus mauritiana* as a source of food and the associated commodity value chains, it can play a significant role in facilitating pro-poor adaptation of rural households to climate change and variability. However, to understand its contribution in building the adaptive capacity of rural communities, it was important to have a clear comprehension on how rural actors combine the use of *Ziziphus mauritiana* with other players such as social networks to build resilience against both internal and external stressors. These issues have been analysed within the broader and contemporary discourse on climate change adaptation and natural resource use.

**Keywords:** Actor network theory, commodity value chains, network thinking, *Ziziphus mauritiana*

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## Investigating Future Pathways for the Cameroonian Cocoa Sector that Lead to a Higher Cocoa Quality and Sustainability, Improving the Livelihood of Farming Households

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The cocoa value chain is of great significance for Africa, especially for West African countries. 70 % of the total cocoa world production comes from this region and many rural livelihoods depend on this cash crop. However, a number of diverse factors limit the production of cocoa cultivation and livelihood improvement in West Africa. Therefore, regarding the persistent poor livelihoods of cocoa farming households, future climate predictions and the pressure of the worldwide demand for higher cocoa productivity and quality there is still a strong need to find new approaches that guarantee a sustainable cocoa future and food security in Cameroon. This exploratory research investigates potential future pathways for the Cameroonian cocoa sector that were developed in the “Potential analysis of innovative approaches for the cocoa value chain in Cameroon” (PotinnocC) project of the International Institute of Tropical Agriculture (IITA) in Cameroon. By doing so, a holistic approach is applied, using theories of scenario analysis and agricultural innovation systems (AIS), to analyse these future possible scenarios within the current cocoa innovation system in Cameroon. Qualitative expert interviews, as well as a focus group discussion capture various perceptions of different actors of the cocoa value chain towards future pathways. Criteria, that is based on sources of the UN (United Nations), FAO (Food and Agriculture Organisation) and ACI (African Cocoa Initiative) is tested to evaluate sustainability dimensions of the pathways. The study shows that certification and a stronger cooperation between the private and public sector are strongly envisioned by value chain actors. The generated results of the study contribute to IITA’s research project PotinnocC and its predicted outcome, which is to enable policy makers and other development agencies to understand the potentials and the hindrances in the cocoa value chain in Cameroon in order to help designing their interventions and strategies in an effective and efficient way.

**Keywords:** Cameroon, cocoa certification, cocoa value chain, future pathways, sustainable value chains

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## Rural-Urban Linkages- A ‘mirage’ or a ‘myth’: Evidence from Rural markets in Eastern Sri Lanka

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In recent years, growing recognition that rural and urban areas have become increasingly interconnected through a constant movement of people, goods, capital, ideas and information. Rural markets in Sri Lanka play the twin roles of facilitating the interaction between retailers, producers and consumers. A rural market study was done in the Ampara and Batticaloa districts of the Eastern Province in Sri Lanka to ascertain the geographical coverage and their links with urban markets. It also attempted to verify von Thunen’s ‘Central Place Theory’ of service centres in a region. Secondary and primary data was used, and a field survey of randomly selected 30 rural markets was conducted. The GIS ARC-Info software was used to ascertain coverage of rural markets. The results indicated that rural markets act as ‘central places’ in both districts, and they covered a relatively moderate geographical area with an average radius of 4.5 kms. Also many of the rural markets had linkages within themselves through traders moving from one market to another market nearby, while only rural markets close to urban areas had links with urban centres. Rural farm products were sparsely moving to urban centres, while products from other district urban markets were being transported to urban centres. This was due to the weak transport facilities in rural areas and poor link roads with urban centres and rural market places. Also most of the rural markets operating periodically have been another causal agent for the lack of strong rural-urban linkages to develop. The study suggests that regional policy should focus on enhancing rural road networks and transport facilities to foster better rural-urban linkages and enhancing rural and urban food security that would help communities to sustain themselves.

**Keywords:** Central places, geographical coverage, markets, rural-urban linkages, Sri Lanka

## **Achieving Food and Nutritional Security through Commercialised Agriculture: The Role of Transitional Systems in Kenya**

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Agricultural commercialisation has the potential of increasing access to diversified foods among households. Increased purchasing power due to market participation enables consumers to afford more nutritious food bundles. However, there is scanty empirical literature on the extent and patterns of agricultural commercialisation in remote rural food-insecure farm-households in Africa. This study provides evidence of how emerging transitions in rural infrastructure and devolved governance systems contribute to market participation by farm-households, which ultimately leads to nutritional diversity in western Kenya.

Primary household survey data from a random sample of 300 smallholder maize farmers was analysed using; descriptive analysis and multiple linear regression. Results showed that, amount of purchased inputs used, household asset index, land size, total output, access to credit and trust in traders significantly influenced commercialisation patterns in transitional systems (with declining land sizes, increased market access). Further, it was noted that support services (inputs, wealth, and credit) had both positive and negative effects on the level of commercialisation in transitional systems. Areas with improved infrastructure especially improved access to all weather roads, had better access to marketed inputs and thus reported considerable increments in the amount of maize sold compared to areas with poor infrastructure. Intuitively, households with high exposure to positive transitions in infrastructure, land management systems and better inclusive localised governance systems for land and support services had higher levels of market participation which ultimately contributed to improved food and nutrition security. The study recommends the need for both County and National government to invest in infrastructure so as to increase commercialisation. More specifically, high access to all weather roads positively contributes to market participation among farmers.

**Keywords:** Commercialisation, food and nutrition security, Kenya, transitions

## Enhancing Sunflower Value Chain for Rural Economy in Tanzania: A Village Computable General Equilibrium-CGE Approach

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Proportionally, in Tanzania, the agricultural sector accounts for about 29 % of GDP, employs 65 % of the workforce, and generates more than 80 % of the total export earnings. Around 28.2 % of the households living below the poverty line are rural households where the main income activity is small-scale agriculture. Intervention leading to generation of employment and access to income is crucial for ensuring food access, and for the poor this is even more crucial, as their labour is often the main asset that they can rely upon for income generation. Hence, developing pathways for securing food and agricultural products value chains in Tanzania provide potential intervention points. Income alternatives to stabilise livelihoods, such as enhancing sunflower value chain, is deemed vital given that food security will not be negatively affected. This study uses a village computable general equilibrium (CGE) approach to assess the welfare effects of sunflower value chain upgrading strategies on labour and income for rural economy in Tanzania. To assess the effects of sunflower value chain upgrading strategies, we construct a village CGE for Idifu village in Dodoma, Tanzania where sunflower value chain upgrading strategies have been implemented by a Trans-Sec project. Results indicate that enhancing the sunflower value chain by increasing the output, introducing value addition through processing and linking sunflower farmers to markets has positive effects in terms of labour, income and household consumption. Consequently, we argue the government and other development practitioners in Tanzania to promote initiatives geared toward enhancing crops value chains which would lead to income generation and improve farmer household's consumption in rural setting.

**Keywords:** Income, labour, sunflower, Tanzania, village CGE

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## **The Rebirth of Natural Fibres? Analysis of Market Potential for Fique (*Furcraea andina*) Production in Santander, Colombia**

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Natural fibres extracted from the leaves of the fique plant (*Furcraea andina*) are currently used by the Colombian market mainly for the manufacture of coffee sacks and crafts. However, the economy associated with the cultivation of fique in the department of Santander is weak and optimal production practices have greatly been abandoned by farmers because of poor market demand in the last two decades. However, new market demand for natural, eco-friendly fibres to replace plastic opens up better opportunities for fique producers. The objective of this study was to provide a macro view of the current fique market in Colombia and its potential in modern markets. The study of production aspects, economic situation and market potential was conducted with 25 producing families where relevant information to characterise the current situation was obtained. Data on production practices, market access and economic situation was collected. The results revealed that fique production can help improve the economic situation of rural families in Santander, but that the production system can be improved and optimised to generate a higher income. Currently, there is a market potential in natural fibres, but more investments need to be made to train farmers in sustainable production practices and compliance with new standards and certifications. Additionally, local artisans need to improve the products they produce with the fibre to meet the new demands in the eco-friendly, natural fibre market. A set of strategies and recommendations for improved market access for small-scale producers and artisans using both modern and traditional techniques was drawn.

**Keywords:** Colombia, fibres, fique, value chain

## The Potential of *Acrocomia* Value Webs for Rural Development and Bioeconomy in Paraguay

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*Acrocomia* ssp is a native palm tree in Latin America which produces rich oil-bearing and drupaceous fruits traditionally used as food and fodder. *Acrocomia* fruits are composed on a dry matter basis by epicarp (19 %), mesocarp (42 %), endocarp (31 %) and kernel (8 %), varying among species and biophysical conditions. Considering a plantation system of 400 palm trees per hectare, suitable to agroforestry, high yields of fruits (20 t ha<sup>-1</sup>) and oil (2.5 t ha<sup>-1</sup> of kernel and pulp oils) are projected. In addition, remaining fruit components have several uses, which makes *Acrocomia* a promising crop in the bioeconomy. Through industrial processing, oil is extracted from pulp and kernel (lipids 45-60 % and 61-68 % dry matter). Husk, endocarp and pressed cakes result as by-products. *Acrocomia* oils have industrial applications in pharmaceutical, cosmetics and food sectors as well as a biofuel source. Husk and shell are used as solid fuels and potentially as input for activated carbon and charcoal. Pulp flour can be used as a food product while kernel and pulp cakes are utilised in animal nutrition. Further applications are being progressively studied, as well as agronomic aspects, cultivation, breeding and crop management. Paraguay, an agriculture-based country located in the Neotropics, is a natural habitat of *Acrocomia*. This wildly growing palm gained economic importance by mid of the 20<sup>th</sup> century with the emergence of industry for oil extraction. It is considered as an alternative crop to diversify income sources for peasant and smallholder family farmers. They represent 80 % of farms in Paraguay and increasingly face multiple socio-economic challenges associated to agribusiness activities. Using the approach of biomass value web as a multidimensional and holistic framework, this research aims to analyse the existing *Acrocomia* value chains in Paraguay, identifying opportunities and constraints for further upgrading. Complementary, a bottom-up *Acrocomia* adoption initiative in the region of San Pedro del Paraná (Dep. of Itapúa) is studied. Through an economic analysis of a small-scale (pre-) processing system of *Acrocomia* fruits, different scenarios for local value addition are built, integrated with an outgrower scheme for the development of inclusive and pro-poor biobased value chains.

**Keywords:** Alternative oil crop, biomass value web, biorefinery, cascading use of biomass, pro-poor value chain, small-scale processing, value chain analysis

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## Rainforest Alliance Certification and its Global Trade Effects in the Cocoa Sector

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The amount of non-tariff measures, applied to guarantee high levels of food quality, such as sanitary and phytosanitary or technical measures, has increased over the last decades. In addition to mandatory quality standards, voluntary food safety as well as social and environmental standards have evolved to meet an increasing demand for safe, high-quality, sustainably and ethically produced food by discerning consumers worldwide.

Since these voluntary standards affect import and exports decisions, the analysis of trade effects of such non-tariff measures has become an important topic during. The standards-as-barriers versus the standards-as-catalysts argument especially, has been controversially discussed. However, scientific evidence remains ambiguous.

This study analyses the trade effects of the private social and environmental standard Rainforest Alliance (RA) in the cocoa sector. This sector makes a suitable example to study social and environmental standards, because it faces three major challenges in production. First, the cocoa sector is characterised by increasing chocolate demand. Second, cocoa farming is expanding, especially into rain forest and protected areas, which can lead to reduction of native vegetation and biodiversity. Third, most cocoa producers are smallholders who rely on family and informal labour.

This study makes four major contributions to the current debate. First, we use a previously unexploited data set provided by RA. Second, we study the trade effects of a social and environmental standard, while most other studies focus on food safety standards. Third, we are the first who use the share of certified land area to total area as a proxy for certification. This allows us to calculate a less biased effect of certification on export flows. Fourth, our analysis is at a global level including 56 exporters and 172 importers over a 9-year period. Previous studies rather focus on one specific import or export region.

We find that RA certification enhances bilateral exports of cocoa. However, the effect remains robust only for raw cocoa beans and cocoa paste and disappears for other processed cocoa products. Finally, we conclude that voluntary food standards are not a suitable instrument to promote sustainably and ethically produced cocoa exports per se.

**Keywords:** Agricultural trade, cocoa, Rainforest Alliance, voluntary food standards

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## The Baobab Processing Sector in Malawi: Strategy, Business Models and Performance

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The baobab (*Adansonia digitata* L.) is an important indigenous fruit tree in Africa. The tree's potential as ingredient in healthy and nutritious food products has increasingly been realised, as witnessed by a growing demand for baobab from the global food and beverages industry and establishment of baobab processing companies in sub-Saharan Africa. However, supply of affordable and high-quality processed baobab products is currently faced with a number of challenges. The paper presents results of a study currently ongoing in Malawi. Since the 2000s, the country is characterized by an intensive commercialisation of baobab by numerous formal and informal food processing enterprises. However, research results with regard to strategy, business models and performance of these enterprises are scant. This study aims to fill these gaps.

The study draws from a survey of 80 baobab processing enterprises, key informant interviews, case studies of four enterprises and secondary sources. The majority of the enterprises in the sample (70) are informal enterprises. The most common product in the informal sub-sector is ice-lollies. The target market for the informal processors are low income bracket (usually school going children). Juice and powder are the most dominant products of formal baobab processing enterprises. This subsector targets high-income health conscious consumers primarily in the domestic urban markets. With regard to business models, results show that a majority of the enterprises employ similar business models with collectors as the main key partner in the factors markets and retailers as the main key partner in the product markets. Preliminary results also indicate that using Miles and Snow's strategic typology, a majority of the enterprises can be classified as reactors. By employing undifferentiated business models and employing reactor strategies, the performance of the enterprises is compromised as evidenced by a number of formal enterprises that had to close down operations. The paper presents recommendations on how to increase the business performance of the formal and informal baobab processing sector in Malawi.

**Keywords:** Baobab processor, business model, performance, strategy



# Universities, networks and training

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## **MYTOX-SOUTH: An Intercontinental Partnership to Improve Food Security and Food Safety in Developing Countries**

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Mycotoxins are toxic fungal secondary metabolites and can contaminate agricultural commodities during cultivation, harvesting, transport, processing, and storage. Mycotoxins are globally distributed and are observed in a vast range of agriculture commodities and environments. This results in contaminated cereal crops, spices, nuts, fruits not suitable for human consumption, leading to enormous economic losses, worldwide. Mycotoxins are present in a wide range of products, from agricultural crops (rice, wheat, rye, barley, corn, soybeans, sorghum, nuts, spices), cereal-based foods (baking products, pasta, breakfast cereals), beverages (fruits, juices and purees, beer and wine), and animal feed to several animal products (dairy products, meat, eggs). Mycotoxin intake may lead to autoimmune illnesses, metabolic and biochemical deficiencies, allergic manifestations, reduction of reproductive efficiency, and may also lead to teratogenicity, carcinogenicity, mutagenicity, and death.

The co-occurrence of different types of mycotoxins results in serious food safety issues all over the world, with sub-Saharan areas being one of the regions at high risk. Moreover, in Africa and other developing countries, the possibilities for regular mycotoxin analysis are scarce to non-existent: analytical tests are expensive; there is a lack of expertise and training; there is insufficient technical support from companies selling analytical instruments, and focus is mainly put on the aflatoxins, while other mycotoxins are being neglected.

To tackle in an efficient and global way the mycotoxin problem the MYTOX-SOUTH partnership was created. MYTOX-SOUTH (<http://mytoxsouth.org>) intends to harness the expertise and infrastructure available at Ghent University to strengthen the capacity of the southern partners to tackle the mycotoxin problem and the associated food safety and food security issues at global level. For this reason, the long-term aims for MYTOX-SOUTH are: 1) building human and infrastructural capacity through training of the Southern scientific community, 2) bridging the gap between research and development, and 3) stimulate the scientific environment to create a sustainable network.

**Keywords:** Aflatoxins, capacity building, mycotoxins

## **Pains and Gains of International Research Collaboration with Academia – Perspectives from an Extramural Research Institute**

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The International Livestock Research Institute (ILRI) is an international, independent, non-profit organisation with the aim to improve food and nutritional security and to reduce poverty in developing countries through research for efficient, safe and sustainable use of livestock. Collaboration with academia has long been an integral part of ILRI's work as it leads to shared learning, sharing of resources, synergies, complementation and shaping of a new generation of scientists and potentially, decision makers.

The BMZ/GIZ-funded Safe Food, Fair Food project (2008–2016) collaborated with eight universities in Africa, two in Germany and one in Japan on food safety research in informal markets in sub-Saharan Africa. We use this project to illustrate examples of collaborative activities including joint research and research outputs, short term trainings to or from the academic partner(s), and models of co-supervision of students. We want to track project fellows and see where they operate today and if they have indeed become 'champions' for food safety policy making.

At the first glance, benefits of international collaboration seem to be more obvious to the academic partners in the South. These include short to long term technical capacity building, increased numbers of research outputs as well as access to research funding, technology and international networks. At the second look, exposure of students and researchers of the North to the environment and context of disease in low income countries will foster mutual understanding and future collaboration on global health research. In their later professional and personal lives, students and junior researchers of both the South and the North will then be prepared to make informed decisions in the event of global public health events and to consider, appreciate and judge global changes in their local, and regional context.

**Keywords:** Academia, capacity building, collaboration, food safety, global health, research for development

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## Promoting Nutrition and Food Security in Africa: Role of University Research, Technology and Innovation

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Attainment of food security remains a big challenge for most governments in Africa including Kenya. Food security is a complex problem in many countries and requires sustainable solutions to ensure that everyone has access to safe food at all times. Food security has been highlighted as a focal area of concern by the United Nations' Sustainable Development Goals (SDGs) and African Union (AU) Malabo declarations (2014). Improving food security situation in Africa requires a multi-faceted approach including looking at alternative strategies and technologies to sustainable crop and livestock production. Most regions in Kenya have been facing severe food insecurity problems as depicted by a high proportion of the population having no access to food in the right amounts and quality/safety. The University of Nairobi in partnership with University of Kassel and other East African universities have implemented a 5 year project on Reducing Losses and Adding Value (RELOAD) aimed at addressing postharvest losses in the food value chains as a strategy of reducing food insecurity. This North to South cooperation has been instrumental in reaching out to young students and innovators in the region who have developed technologies and innovations that are transforming the lives of pastoral communities and poor households in Africa. The University has also partnered with the Food Security Center of the University of Hohenheim with PhD Programs on "Global Food Security". This interdisciplinary collaboration incorporates a multi-faceted strategy that includes diverse approaches and expertise to tackle food insecurity. This paper presentation will give details of some of the top 5 technologies and innovations that have been disseminated to reduce food insecurity and generate incomes for rural poor in Kenya as developed by over 10 postgraduate students and top scientists in these institutional collaborations.

**Keywords:** Food safety, food security, innovation and technology, institutional linkages

## Educating for Sustainable Food Value Chains: Insights from an Open Online Course

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The 2030 Agenda recognises that food value chains (FVCs) play a leading role in ensuring food security and the implementation of the Sustainable Development Goals (SDGs). SDG 4 “Quality education” emphasises the role of universities in this context. Tertiary education institutions are increasingly responsible for providing free and open access education. Digital educational formats such as eLearning and MOOCs (Massive Open Online Courses) offer enormous potential for global, inclusive and high-quality education.

The Zurich University of Applied Sciences has developed a free and open eLearning course to educate students around the globe about the design of sustainable food value chains focusing on the UN SDGs. The eLearning consists of three modules and is accessible online (<https://gof-summerschool.org/elearning/>). In order to improve the learning impact, the course was developed in an iterative process. After the development phase, we evaluated the eLearning with 30 students from our summer school “Geography of food”. The results of the evaluation were used for adaption of the whole course. And a further, second round evaluation will be conducted.

The most stated message was, that the eLearning “was fun, interesting and kept me focused on the topic”. The majority stated that they learned a lot. However, the participants criticised that the third module of the eLearning was not as interesting as the others. Considering this feedback, we unified the design of the three modules and redesigned the third module, putting a strong focus on enhancing the storytelling-aspect and graphical layout.

We conclude that the success of the eLearning is closely related to its attractiveness (storytelling, graphical layout, interactivity). This is proved by the negative feedback for module 3, where the focus on storytelling and graphical layout was weaker. To provide an international success, other aspects like the simple registration-process and the focus on an international environment may be important. In conclusion, the following requirements have been identified as essential to achieve maximum impact:

- Unrestricted and easy access
- An attractive learning environment
- Scientifically sound, relevant content

We see great potential in free online eLearning, where universities can contribute to accessible and inclusive education to improve knowledge about food security. Stronger North-South cooperation and collaboration with interaction designers could further increase the positive impact of such projects.

**Keywords:** eLearning, scientainment, SDGs, sustainability, sustainable food value chains

## **Making Sense Together? The Role of Academics in the Co-Production of Knowledge for Local Food Governance in South Africa**

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This article seeks to bring more clarity on the role of scientists in the co-production of knowledge for food security. Food systems in South Africa are in transition. Universities can play a particularly important role in facilitating the effective dialogue between academics, civil society and policy-makers that is essential to navigate these transitions. However, integrating scientific knowledge with social, ecological, political knowledge through participatory processes ('making sense together') calls for a reorganisation of science: where researchers become part of the same process that the knowledge they offer aims to inform. Yet much of the research on the new role of scientists in producing knowledge is theoretical and empirical verification is often lacking. This article constructs an analytical framework based on the existing science policy studies literature that incorporates three stages: 'problem exploration', 'problem puzzling', and 'problem solving'. The article then tests this framework against the experiences of scientists in the co-production of a local government food security policy in South Africa. The Western Cape Provincial Government Household Food and Nutrition Security Strategic Framework was drafted in 2015 and 2016 by a team of policy makers and academics through a series of collaborative workshops and interviews with key stakeholders. The aim of this process was to embed scientific and political knowledge in context specific knowledge using a 'whole of society approach' deliberately crowding in a diverse range of individuals, organisations and departments to identify strategic priorities and opportunities. The analysis reveals some key lessons as well as likely challenges that could guide food security scientists who wish to engage in the co-production of knowledge in future.

**Keywords:** Co-production of knowledge, food security, science policy interface, South Africa



## Farmer Researcher Networks as Instrument to Develop Smallholders' Adaptive Capacity

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Densely populated countries with long coast lines in the tropical zone are highly vulnerable to climate change. Indonesia with more than 50,000 km coastline is such a hotspot and prone to multiple hazards - drought, floods, precipitation-triggered landslides and sea-level rise. Since 1990 the temperature has increased by 0.3°C per decade reaching critical heat stress levels for rice production. Rice is an important crop in Indonesia with 90 % of the rice being produced by the 37 million small-scale farmers. These smallholders are often neglected by national policies for climate change adaptation. Therefore scholars and practitioners developed a climate field school approach that has been officially recognised by the government and presented as best practice in international platforms, e.g. at the COP23 in 2017. Climate field schools and agrometeorological learning have been proven to increase the adaptive capacity of farmers.

In the climate field school approach two different kind of knowledge schools are brought together: practical knowledge of farmers and academic knowledge of university staff. Farmers are enabled to monitor, document and assess the results of on-farm trials in the field (=farmer researcher). Scholars understand how to translate and make use of academic knowledge in a solution-oriented manner, including the development of training handbooks and hands-on assessment methods. The implementing organisations act as knowledge brokers between academic and practice at local, and upscale knowledge to regional and national levels.

Tested and new climate resilient agricultural practices of rice farming are trialed on farmer's fields. It comprises the system of rice intensification, stress-tolerant rice varieties, floating paddy fields to integrated rice-azolla-duck-fish-farming. The costs and benefit analysis of selected practices from 8 villages located in West Java and South Sulawesi indicate the challenges of introducing new farming techniques. Moreover, a multi-stakeholder research process that brings farmer researchers, academic researchers and farmer organisations together requires a long-term platform to unlock its potential. Putting farmers' aspirations and needs in the centre and a multi-level solution space are the keys to success for building adaptive capacities for climate resilient agriculture.

**Keywords:** Adaptive capacity, climate change, climate-resilient rice production, farmer field school, knowledge systems

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## South-South Learning to Advance Cavy Culture in Sub-Saharan Africa

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Local knowledge reflects the wisdom and accumulated experiences of many generations and testifies continuous adaptation. Local capacity-building systems, such as farmer-to-farmer training and peer-to-peer knowledge transfers, are effective means for increasing access to knowledge and services. PROCASUR has developed and implemented alternative learning tools: learning-routes and learning-territories (LT).

Peer-to-peer learning and South-South networking is encouraged by an emerging cavy network. Cavy (*Cavia porcellus*) culture R&D, good practices for cavy husbandry, and their benefits to communities have long been established in Peru and Bolivia. In sub-Saharan Africa (SSA), however, there is ample potential to further develop the current knowledge on cavy prospects for harnessing innovation, supporting entrepreneurship, and advancing opportunities for smallholder cavy producers. The first comprehensive cavy project in SSA (realised by the International Livestock Research Institute, ILRI, with partners in Cameroon and DR Congo, 2011-2014) identified cavy meat as alternative animal-source protein accessible to poor and vulnerable people. Furthermore, it established that women and youth especially benefitted from the cavy value chain.

South American and SSA stakeholders met at an International Cavies Symposium in Cameroon in 2016. This provided a forum for peer-to-peer learning and South-South networking among stakeholders from universities, research institutions, NGOs and farmer associations. Institutional progress made since the Cameroon-Symposium reflects the stimulus that this first South-South encounter provided to participants. Incipient intra and inter-continental communication has evolved, even incentivizing some Congolese to learn Spanish.

Since 2017, a Cavy-LT in Peru is operational with 'Local Champions', who act as peer-to-peer trainers supported by over 100 trained cavy producers. Producers are organized in a territorial business network providing the institutional framework and policy support for the functioning of the cavy value chain. In the last 24 months, the Cavy-LT has trained 622 Peruvian cavy producers (38 % female; 18 % young people), generating additional income, including the sale of productive inputs (e.g. breeders). Eleven Bolivian peers visited the Cavy-LT in 2018. They exchanged knowledge of good practices in reproduction management, biosecurity, feeding, slaughtering and marketing of cavies. There are plans that Peruvian cavy entrepreneurs will provide their expertise to peers from Cameroon and Congo in exchange visits.

**Keywords:** Bolivia, Cameroon, *Cavia porcellus*, Democratic Republic of Congo, guinea pig, learning route, learning territory, livelihood, livestock, local champion, mini-livestock, peer-to-peer learning, Peru, smallholder

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## Training Videos to Strengthen the Contribution of Agricultural Professional Training Centres to Food Security and Safety: Case of the Songhai Center in Benin Republic

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Due to a lack of resources the training of professionals in agriculture often suffers from a good balance of theory, practice and field visits. This obviously reduces the contribution of professional training centres to food security and safety. For several years, Songhai Center in Porto Novo, Benin, has downloaded farmer-to-farmer training videos from the Access Agriculture video portal and screened these to their trainees at weekly events. All videos were shown in French and featured farmers from different parts of Africa, Asia and Latin America. The videos focus on agroecology. From July to December 2016 we interviewed 111 randomly selected trainees who attended the video projections to assess the contribution of videos to their training. About 96 % of the trainees found the content of the videos useful and relevant, and estimated that the videos contributed for 15 % to their knowledge, similar to the contribution of theoretical classes. The graduates currently watch videos to acquire new knowledge (78 %) or to review previous notions (29 %). About 33 % of the trainees use videos to train their farm workers and farmers in their villages. The trainees said that the videos connect contexts and allow them to learn from experiences of farmers with different cultural backgrounds. The trainees were willing to pay about 2.6 USD to buy a DVD with training videos. This study confirms that agricultural professionals do not experience any cultural barriers when learning from farmer-to-farmer training videos that are made to good quality standards and that build on adult learning principles. South-South learning between practitioners strengthens in a cost-effective way the training of young agricultural professionals by creating a better balance between theory, practice and field visits.

**Keywords:** Agriculture, Benin, professional training, Songhai Center, video mediated learning, West-Africa

## **Advantages and Opportunities for Collaborative Research between Universities and NGOs to Strengthen Food Security**

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Humana People to People (HPP) is a federation of 31 locally registered and managed non-governmental organisations on five continents. Improving the food security of the rural poor through the provision of extension services is central to their work in the global South. A recent meta-analysis of these so-called farmers' clubs aimed to compile lessons-learned to-date.

The farmers' clubs approach was first used in 2006 and has since been applied in more than 330 projects. Currently, approximately 90,000 farmers participate in the programme across 14 countries in Africa, Asia and Latin America. Participants are organised into groups of 25–50 through which they receive training, tools and resources to sustainably increase production and income using locally-appropriate farming methods.

A meta-analysis completed in 2017 had the objective to provide an overall assessment and review of external evaluations of farmers' clubs projects that were carried out in different contexts and countries to identify good practices, commonly faced challenges and trends. It serves as an internal review on what has been learned to date, and to identify opportunities for improvements in future projects.

This paper outlines the added value of collaborative research for improved food security showing a concrete example of initial research done on farmer clubs. While extension services and NGOs can benefit from a scientifically solid evaluation of their impact on food security, the research community can gain from tailoring their project design and results presentation according to the needs of the NGOs. Moreover, stronger collaboration in research initiatives is likely to increase take up by NGOs and extension services in the field, thereby improving the impact that research results may have on food security. The paper will further explore opportunities for collaborative research on farmers clubs taking into account the extension service model's flexibility and outcomes from the meta-analysis.

**Keywords:** Collaborative research, extension services, farmer clubs, food security

## Technology Transfer and Capacity Building in Biotechnology and Biosafety for a Sustainable and Intensified Agriculture in Africa

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The IPBO (International Plant Biotechnology Outreach) promotes access to scientific and technological innovations as ways of enhancing food security and promoting a sustainable intensification of agriculture. Innovations in biotechnology hold massive opportunities for developing a more sustainable agriculture. However, converting these opportunities into practice in emerging economies requires a concerted effort in training in – and access to – the latest technological developments and the design of effective biosafety and regulatory mechanisms. IPBO is an active cell within the VIB, Belgium (Flemish Institute for Biotechnology) created by Prof. Marc van Montagu in 2000. The mission of IPBO is threefold: (1) improve understanding and create awareness about the importance of green biotechnology applications for sustainable development (communication), (2) empower plant biotechnologists and plant breeders from developing countries and emerging economies through training and capacity building in plant biotechnology and biosafety (training), (3) act as a focal platform for green biotechnology in Europe and leverage outreach to developing countries and emerging economies. For instance, with support of the Flanders Government, IPBO has joined forces with the UN Industrial Development Organisation (UNIDO, Austria) to set up the International Industrial Biotechnology Network (IIBN, [www.iibn.eu](http://www.iibn.eu)). This network is being used to work out projects linking Flanders, European-Asian and American scientists or companies at one side and African partners at the other side.

Under IIBN, agricultural constraints that are potential targets for biotechnology interventions are being mapped in different parts of the world, especially in sub-Saharan Africa. Also, a member-based cooperation network is being developed. Together, these efforts will create an effective platform for identifying new opportunities for cooperation.

**Keywords:** Africa, plant biotechnology, sustainable agriculture

## Use of Research Evidence amongst Agriculture Decision Makers in Sub-Saharan Africa

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The outcomes from different approaches to sustainable agricultural intensification (SAI) is highly contested, such as between agrochemical input-based and agroecological intensification. The SAI research and learning in Africa programme ([www.sairla.nri.org](http://www.sairla.nri.org)) aims to identify and generate research evidence to inform how poorer small-holders, women and youth may better access and benefit from SAI. But what is the demand and capacity to use research evidence by decision makers in agricultural development? Ninety-seven decision makers from government, civil and private sectors across six African countries (Burkina Faso, Ghana, Ethiopia, Malawi, Tanzania and Zambia) completed a self-assessment of their demand for and use of research evidence. This was complemented with 39 semi-structured interviews with key informants and revision of the main agricultural policy documents in the different countries. At least fifty per cent of decision makers actively sought research evidence, although this was lower in private sector respondents (only 33 %), while over 70 % in other groups. A majority of respondents consult evidence on at least a yearly basis, with government and research organisations being the main sources. Content of research evidence was weakest on issues of gender and generational equity, as well as on social and environmental trade-offs. Over 80 % of respondents consider they had a moderate to very good opportunity to apply research evidence and would receive recognition for doing so, thus indicating motivation to use research evidence was high. While a majority of researchers considered that the influence of research evidence on policy was weak, a majority of government sector thought it was strong. Review of agricultural policy documents indicated that the majority included consideration of social and environmental sustainability. However, responses from key informants indicated that the implementation of these aspects of policy was weak, often due to conflicting interests. Therefore, we conclude there is interest amongst African decision makers to use research evidence, but they lack the evidence and tools to implement environmental sustainability and social equity in agricultural development.

**Keywords:** Environmental sustainability, informing policy, social equity, sustainable agricultural intensification

## Relationship between Trainers' Qualification, Learning Success and Satisfaction for Agricultural Capacity Development in Bihar, India

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Within capacity development, the type and quality of the trainer can play a crucial role in promoting farmers' capacity. Hence, the main purpose of this paper is to examine the relationship between trainers' qualification and learning success and satisfaction of small-scale farmers during training activities in Bihar, India. Moderated mediation analysis is utilised to measure the direct and indirect effects of trainers' qualification on learning success and satisfaction. Therefore, the psychological constructs of attitude and perceived control from the theory of planned behaviour (TPB) operate as mediators, subjective norms act as moderator, and gender and age serve as covariates. The results do not indicate a distinction of satisfaction among farmers regarding trainer qualification. However, learning success decreases with an academically educated trainer. The change of attitude during the training has a significantly positive influence on satisfaction. Subjective norms also influence the participants' satisfaction positively. Thus, we suggest for practical implications combining an expert trained on-the-job as the main trainer with an academically educated trainer integrated via modern technologies. In addition, the social environment has to be addressed within the training. Besides the professional background, it is important that trainer gets trained on teaching methods and other soft skills. The results further show that the behavioural constructs are relevant in the field of agricultural education and extension. Theoretical implications can be drawn regarding the improvement of this conceptual framework and other related studies. Whilst various studies have addressed the identification of farmers' capacity development preferences, few have investigated the relationship between trainer qualification, learning success and satisfaction.

**Keywords:** Agricultural training, attitude, moderated mediation, perceived control, small-scale farmers, subjective norm, trainers' qualification

## Empowering Young Scientists on Food and Nutrition Security and Right to Food in Sierra Leone

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Sierra Leone belongs to the poorest countries in the world and has emerged from a decade long civil war in 2001. This war has led, amongst others, to a dramatic reduction of food availability and a serious brain-drain which adversely affects the human capacity in the country on the long term. In the recent years, Ebola outbreak counteracted the country's development. The food and nutrition security situation remains precarious and a lot of effort is needed to improve livelihoods of people in Sierra Leone.

Njala University is the only Sierra Leonean university combining programs in agriculture, food technology, nutrition, and home economics, which aim directly at improving knowledge on food and nutrition security, at one institution. The university had to leave the campus during the rebel war and was re-opened at Njala Campus in 2005. During the Ebola outbreak it had to be closed again. Brain-drain at university level and partial destruction of physical infrastructure still require long term assistance.

The Food Security Center of the University of Hohenheim combines scientific expertise in agriculture and nutrition with broad visibility and, thus, was asked to coordinate a partnership in training and research between the University of Hohenheim and Njala University, specifically in the field of "International Food and Nutrition Security and the Right to Food" (NutritionSec).

The NutritionSec project aims at qualifying university lecturers at PhD and PostDoc level, as well as future professionals at MSc level on Food and Nutrition Security and the Right to Food. Lecturers of both universities participate at joint existing teaching programs in Germany. In addition, they develop innovative MSc modules at Njala University in close collaboration taking into account the local conditions in Sierra Leone. These MSc modules will qualify future professionals to support the country's recovery from the serious brain-drain in the past decades. In addition, the teaching infrastructure of Njala University is upgraded to ensure up-to-date high quality education. These measures should significantly contribute to improving the food and nutrition security situation in the country.

**Keywords:** Curriculum development, international cooperation, research and education, train the trainer, Western Africa

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## The Academy Generates Solutions for Food and Nutrition Security in Colombia

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Food security and nutrition is a complex challenge that requires a complex approach to face it. McGill University from Canada and the National University of Colombia, formed a multidisciplinary team that in a transdisciplinary work linked social sciences and natural sciences and developed a technological innovation, the most nutritious potatoes. These potatoes offer higher nutritional contents such as iron, zinc, dietary fibre, protein and polyphenol compounds that protect the health. These varieties were selected in participatory research with communities. These potatoes offer 18 % more income to small-scale potato farmers, because they are more resistant to the most devastating disease in this crop and the yield is the double compared to the most cultivated variety in the country. It is expected that, at the end of the second semester of 2018, these new varieties will reach 13 million consumers in Colombia in accumulative way. This project developed knowledge for the two participating universities and linked the postgraduate academic programs in gender studies, food and nutritional security, agricultural sciences and rural business development working collaboratively with McGill University. Undergraduate students, masters and doctoral students were trained and results were generated for policy makers on issues of nutrition, gender and social equity, and environmental protection. We developed a model to scaling-up a technological innovation based on social innovations and we generated the pillars to establish a system to produce good quality of seed potatoes for Colombia.

**Keywords:** Gender equity, linking agriculture and nutrition, scaling-up

## Science-Policy-Practice Interfaces in Agricultural Innovations in Africa: Moving beyond the Traditional Boundaries of Doing Science

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Agricultural innovation pathways have developed since the beginning of the 20<sup>th</sup> century from the linear model of transferring knowledge, technologies and practices from ‘sources’ (universities, research centres) to ‘receivers’ bridged through the extension system to the current approach of joint collaboration between stakeholders. However, there are no sufficient guidelines on how scientists can effectively engage with policy makers in research and knowledge sharing. Within the BMBF-funded Biomass-Web project ([www.biomassweb.org](http://www.biomassweb.org)), we aimed at filling this cooperation gap through research-policy-practice interfaces (RPPI) based on the concepts of transdisciplinarity and research for development (R4D) continuum. The research process followed four main stages to create RPPI: (1) BiomassWeb researchers formed (interconnected) teams along the chains of production, processing and marketing biomass-based products in selected sub-Saharan African countries (Ethiopia, Ghana and Nigeria); (2) researchers participated in training workshops on participatory research methods; (3) workshops were organised for the researchers to evaluate and collate lessons learned from their practice of participatory methods; (4) BiomassWeb research findings were shared, among others, through science-policy dialogues. On the one hand, researchers were required during the evaluation workshops to reflect on their approaches to interactions with stakeholders and adapt their approaches to the contexts during the research and, on the other hand, broaden the channel of communicating scientific knowledge in a way understandable to policy makers. The knowledge sharing during the science-policy dialogue has led to jointly identifying and reflecting on the mechanisms to address concerns of policy makers and practitioners to implement the findings. The need for continuous research to address some of the problems that arise in the process of implementation has also been recognised by both researchers and policy makers. Therefore, without undermining the role of universities and research centres in knowledge and technology production, we argue that universities can engage with policy makers through stakeholder participation, science-policy dialogue, providing evidence continuously and facilitating the process of learning lessons for successful implementation of agricultural innovations in Africa.

**Keywords:** Innovation communication, R4D, transdisciplinarity

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## **Fostering Multi-Stakeholder Co-Learning for more Sustainable Resource Use and Improved Livelihoods in Mozambique**

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The central Mozambican provinces are climatically quite diverse. While some provide farmers with favourable environments, others make agriculture a complicated and risky endeavour for the hard-working and persistent. In Marara, in Tete province, the climate is semi-arid, around 600 mm of rain fall every year, but in just two months. In El Nino years, there is even less rain if any at all. The local farming systems are mostly rain-fed, and integrate crops and livestock. Goats, and to a lesser extent also cattle, are the systems' backbone. Information and inputs are hard to come by for farmers. Extension services are underequipped and cannot provide as much support as would be desirable.

In this challenging environment, our project seeks to understand how we can support a transition to more sustainable resource use and improved livelihoods for farmers. By using an open innovation platform approach, we aim at improving social and professional linkages between all actors: farmers, extension, private and governmental sector. Following a participatory identification of strengths, threats, opportunities and weaknesses, we provided technical trainings, encouraged experimentation and facilitated analysis. We want to build capacities and to foster co-learning of all actors. To stimulate self-organisation and to facilitate linkages with market actors and extension services, we included modern information and communication technology in the project set-up.

To accommodate farmers' deep interest in soil, we developed a soil health training that was tailored to the specific context in Marara. We visited several members of the innovation platform in their fields and interviewed these farmers about challenges and mitigation strategies. We prepared information on soil processes, related it to current agricultural management practices in the area, and chose four fields to visit with participants during the training. We documented several stages of the training implementation using video equipment. The trainings ended with a feedback workshop. Here, we want to present experiences with this type of training and lessons learned, as well as set these in relation to feedback from screenings of our video in several different settings.

**Keywords:** Extension, film, innovation platform, participation, training

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## Maize Is Not the Only Food – What Can Universities Do about This?

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HealthyLAND is a collaborative research project, involving two German and three African universities in Kenya, Malawi, and Uganda. All universities have long-term experiences in agriculture and nutrition research. The project aimed at a better understanding how to improve the linkage between crop and dietary diversity. Besides assessing the nutritional status, crop and dietary diversity of poor farm families, agricultural and nutrition education interventions were conducted in the project areas.

During 2016, the research team (nutritionists, agricultural economists and agronomists) conducted an agriculture-nutrition-baseline study at all three African research sites. The findings confirmed that farmers' diversification levels were poor. The most common crop grown by the farmers was maize, with very little legumes and vegetables. Additionally, it was found that dietary diversity was poor. Focus group discussions revealed root causes like population density (need for starch), and perceived "food security equals maize".

All researchers agreed that a paradigm change is needed towards improving agrobiodiversity for diverse diets, and that "the food-equals-maize-thinking" is fostering malnutrition as well as soil degradation. However, in the HealthyLAND implementation phase curiously agricultural researchers were reluctant to design an intervention without research on maize practices. Farmer field schools were established with maize intercropping systems, including distribution of maize seeds as preference of stakeholders. It was argued that maize was used to interest farmers to participate. "Maize might be used for own consumption but also as cash crop". This hindered the development of innovations of other crops than maize.

Discussions among the research team members showed that maize production is still highly embedded in local universities training, attitude and practice of lecturers, neglecting all the negative impacts on both human diet and soil degradation. We think the problem is also embedded in a crude and odd discussion about terms such as food security if neglecting nutrition norms. Looking for reasons is urgently needed, though normative. Policy makers and stakeholders in the agricultural sector as well as the nutrition sub-sector have a major responsibility for changing own people's perceptions and attitudes on food. It requires a paradigm change in research, university training, school education and farmer training, too.

**Keywords:** Agriculture nutrition linkage, food security, maize, university training

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- Production of healthier food might lead to reduced sustainability (increased energy use);
- Healthier food choices hardly respond to market incentives and more to social norms;
- Investments in waste management tend to increase market volume and lead to lower prices.

This 3-I framework is useful to support exchange between academic disciplines and to guarantee engagement of multiple stakeholders.

**Keywords:** Food systems, interdisciplinarity, multi-stakeholder

## Production and Genetic Conservation of Quality Protein Maize (QPM) Seeds by Smallholder Farmers in Karamoja Sub-Region, Uganda

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The need for improving availability and access to pure quality maize seeds of protein content instigated the commencement of a programme for production and conservation longe5 seed revitalisation system. Longe5 is a maize variety with two amino acids called *tryptophan* and *lucine* that codes protein synthesis. This study aimed at (i) Creating a multi stakeholder innovation platform for commercial production of pure quality Longe5 maize seeds (ii) Training and equipping farmers with practical grower and protein preservation knowledge; (ii) Quality control and marketing of pure quality Longe5 seeds in a sustainable venture (iv) increasing seed volumes through block farming. Successes achieved involved application of effective methodologies including: (a) establishing an inter-linkage platform for sourcing production and marketing information used in QPM seed system; (b) application of nucleus and farmer field school perspective for practical farmer training (c) application of isolations and half-sib methods for genetic purity conservation and (d) establishing block fields for seed production. Four farmer groups were formed each comprising of 30 farmers across selected districts. Under a comprehensive method, farmers commenced with use of foundation seed stocks and produced quality declared seed and finally pure quality seeds after three seasons. The project registered the following benefits including: (i) Platform for QPM seed enterprise established and functionalized (ii) favorable contract agreements for commercial seed scheme developed and operationalized (iii) model for QPM seed profit margin analysis for crop enterprise selection developed and (iv) 5 farmer groups under FFS made operational (v) 60 % trained in production and marketing and consumption of QPM maize seed systems (vi) 79.9 % of farmers applied half-sib method at various isolation perspectives (vii) 100MT of pure QPM maize seeds were produced. Currently growers are knowledgeable of the values, benefits of longe5 seed production, access and availability especially at planting time.

**Keywords:** Farmer, half-sib, quality protein maize purity, smallholder

## **Integrating Research Instruments for the Assessment of Transformative Sustainability Learning**

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If higher education for sustainability is to be advanced, we need to evaluate the effect of specific learning experiences on sustainability values, skills and behaviour. The Transformative Learning Theory seems to be particularly suited to capture such learning processes. There is, however, agreement in the literature that the impact of learning experiences is difficult to assess, as the course setting is only one of many aspects of the students' lifeworlds. Student biographies are not characterised by linear causalities, and even the students themselves may have difficulties identifying transformative learning moments. Moreover, studies on higher education for sustainability have been criticised for methodological weaknesses. Scholars of transformative learning in particular have questioned the ability of quantitative research instruments to capture the messy space of transformation.

We do believe, however, that those promoting novel forms of sustainability learning at universities will need efficient instruments to assess learning designs and to argue for course and curriculum adaptation. Accordingly, we developed a research instrument based on established concepts: the survey of the Graduate Study Cooperative (KOAB), the Transformative Learning Survey and the Environmental Attitudes Inventory (EAI). We then tested the instrument with 117 alumni of the International Training Course on Organic Agriculture.

The KOAB served as the basic structure and captured the characteristics and current professional position of a respondent. It also contrasted the capabilities acquired at university with the actual professional requirements. To apply the Transformative Learning Survey to a specific learning experience, we adapted the wording and re-

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duced the number of scales to four: 1) Acting differently, 2) Cognitive/Rational, 3) Open perspectives, and 4) Social responsibility. Considering our interest in sustainability behaviour, we also integrated items of the Environmental Attitudes Inventory. To test the factorial validity of the scales, we applied Confirmatory Factor Analysis (CFA). All CFA models showed an adequate to excellent model fit (CFI: 0.91–1.00, TLI: 0.91–1.05, RMSEA: 0.000–0.069) In addition, reliability coefficients of all scales were satisfactory to good. Despite the limitations of ex-post studies based on self-reported perceptions, we conclude that the newly developed survey instrument could become a useful tool for advancing sustainability learning.

**Keywords:** Evaluation, quantitative assessment, research instrument, sustainability learning, transformative learning



## Effects of a Transformative University Learning Experience on Sustainability Agency, Skills and Pro-Environmental Attitudes

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The purpose of this study was to analyse the transformative potential of an intensive, transdisciplinary university course in training sustainability agents using the case of the International Training Course on Organic Agriculture (ITCOA). The ITCOA is a programme organised annually for three weeks in Uganda. Initially, the consortium consisted of Makerere University Kampala (Uganda), University of Natural Resources and Life Sciences-BOKU (Austria), and Sokoine University of Agriculture (Tanzania). The University of Nairobi (Kenya), Bahir Dar University (Ethiopia) and Uganda Martyrs University joined later on, and BOKU-Austria has now fully transferred its coordinating role to the East African partners who have further developed the program. Each participating university nominates excellent undergraduate students from different disciplines for the course, and the annual number of participants varies between 32 and 40. This study analyses the training courses from 2005 to 2014. We integrated concepts of sustainability learning and the Transformative Learning Theory into a research instrument, building on the survey of the Graduate Study Cooperative, the Transformative Learning Survey and the Environmental Attitudes Inventory. To our knowledge, this is the first study applying the Transformative Learning Survey combined with other instruments to a specific learning intervention. 117 ITCOA alumni participated in our study. To analyse the data, a path model was set up. The results showed that the ITCOA provided a transformative experience that positively predicted the participants' sustainability agency, empirically defined as the feeling of having a personal influence on sustainability and the perception of the employer's influence on sustainability. The learning experience also predicted the pro-

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fessional and personal competencies at graduation and environmental attitudes. While we are aware of the limitations of ex-post studies based on self-reported perceptions, we conclude that the ITCOA as a transdisciplinary learning design is an example of transformative sustainability learning - forming knowledge, attitudes, and skills. The design creates experiential space for transformative social learning, particularly in the affective domain. Our study thus helps to argue for further research, monitoring, and a wider reform of sustainability learning at universities.

**Keywords:** Agency, attitudes, organic agriculture, skills, sustainability learning, transformative learning, university learning

## Exploring the Power of Innovative Learning with Farmers for Sustainable and Remunerable Agriculture

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New and emerging technologies may have the potential to tremendously improve the future of crop and livestock production in developing countries. However, harnessing the potential of such technologies for food security requires investments in research and development, human capital, infrastructure and knowledge flows.

For the last five years, HORIZONT3000 has been implementing Enabling Rural Innovation in East Africa (ERI EA); a regional rural development project that works through capacity building, knowledge management and strategic partnerships to benefit rural farmers and their communities to enhance and balance their food sovereignty, income security, and sustainable natural resource management. It uses the Enabling Rural Innovation (ERI) approach developed in East Africa by the International Center for Tropical Agriculture (CIAT) to overcome the linear, top-down model of technology development and market access in agriculture.

In order to further create an enabling environment for agricultural innovation that benefits farmers and university students, since 2016 HORIZONT3000 partnered with Makerere University, Uganda Martyrs University, Sokoine University of Agriculture Tanzania, University of Nairobi Kenya and Bahir Dar University Ethiopia under the International Training on Organic Agriculture (ITCOA). Through this interactive knowledge sharing process together with farmers, students learnt about the working of ERI approach by applying its five key modules of: Participatory Diagnosis, Participatory Market Research, Farmer Participatory Research, Enterprise Development, and Participatory Monitoring & Evaluation. On the other hand, students shared practical knowledge of agro ecosystem health assessment and use of a mobile soil testing kit with farmer groups and field extension staff in Rakai and Tororo districts.

Project annual reports and monitoring reports for 2016/17 showed that shared knowledge and experience led to improved soil and water management practices and as a result, food production volumes (especially cereals and legumes) more than doubled. Obtained knowledge has also been applied in establishing and maintaining simple vegetable gardens around homesteads (kitchen gardens) that further supplement the quality of daily meals consumed rural farming families in the project area. Empowering farmers and the youth with relevant application knowledge will be the best way to tackle the big challenge of food security and nutrition in the twenty first century.

**Keywords:** Food sovereignty, innovative learning, natural resource management

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# Towards sustainable livelihoods

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## Changing Climate – Changing Livelihood: Farmer’s Perceptions and Adaptation Strategies, Indian Watershed Context

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Climate change impacts are disproportionately distributed across the temperate and tropical regions. Most of the countries in the tropics and subtropics will be the hardest hit by climate change with a decline in agricultural production, increased livelihood insecurity, and downward spiral in human development indicators. Moreover, these countries own large populations of poor smallholder farmers who live in a ‘complex, diverse and risk-prone’ system, which adds to their vulnerability. For example, India’s smallholder farmers comprise 78 % of the country’s farmers and they produce 41 % of the country’s food-grains. As climate change impacts are increasingly observed and felt by these smallholders, there is an urgent need to identify the factors that enhance the adaptive capacity of farmers, their households and communities. We, therefore, use the recently developed climate vulnerability index for rainfed areas based on data from 215 household surveys in three different watershed smallholder communities in Kerala, India to analyse the farmer’s vulnerability to climate change. We are interested in examining how households perceive climate change, how they adapt their behaviour in response to perceived changes in climate and what the main drivers in influencing the household’s choices of adaption measures are. The results reveal that 85.3 % of the farmers perceive ‘medium-high’ level of considerable rise in temperature while 66.1 % of them perceive erratic monsoon occurrence over the past ten years. We find that there exists a considerable variation for the three regions when it comes to the actual use of adaptation strategies but that, in general, the households are using various adaptation methods simultaneously. Results of a binary regression model reveal that gender, age of the household head, household size, net sown area, household assets and poverty status of the household significantly influence the choices of adaptation measures used to cope with climate change.

**Keywords:** Adaptation strategies, climate change, rainfed, smallholder farmers, watershed

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## Multiplier Effects and Food Security Outcomes of an Increased African Indigenous Vegetable Demand in Kenya

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Despite continuous efforts of policy makers to improve food security outcomes in the country, Kenya is still among the countries with the highest micronutrient deficiency worldwide. African indigenous vegetables (AIVs) can be an answer to this problem thanks to their high contents of micronutrients. In fact, those crops have seen a rise in appreciation and demand in urban areas of Kenya over the last decade. Income effects for farmers adopting AIVs are ambiguous and depend on the availability of assets, markets and public infrastructure. However, measuring only direct effects can understate the income and food security effects of an increased demand of AIVs on the rural population. Thus, the following research questions arise: a) What are the characteristics of food insecure households in the villages? b) Which crop has the best direct and indirect income effects for food insecure households?

For the analysis, a total of 706 small-scale vegetable producers were interviewed in Kiambu, Nakuru, Kakamega and Kisii County in Kenya in 2015. A two-step cluster analysis is applied to the sample with several food security indicators to cover the multidimensionality of food security. This way, households are grouped into food secure and food insecure households in peri-urban and rural areas. A social accounting matrix is then generated to show direct and indirect income effects of different food secure households in the village economy. Results show a significant higher prevalence of food insecurity in the rural areas especially in the utilisation and stability dimension. Food secure producers have higher levels of education and own more land, have more income from off-farm employment and less from crop production than food insecure ones. AIVs have higher multiplier effects in the village economy than many traditional cash crops like coffee, tea or maize. Among rural food insecure households, especially the less commonly produced AIVs such as Miroo (Slender-leaf - *Crotalaria ochroleuca*), Murenda (Jute mallow - *Corchorus olitorius*), Pumpkin leaves (*Cucurbita moschata*) and Enderema (Vine spinach - *Basella alba*) have the highest income effects.

**Keywords:** African indigenous vegetables, cluster analysis, food security, Kenya, social accounting matrix

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## **Women's Indigenous Knowledge and its Contribution to Sustainable Livelihoods: The Case of African Indigenous Vegetables in Kenya**

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This paper aims at demonstrating the important role of indigenous knowledge and its contribution to sustainable livelihoods through an investigation of the African indigenous vegetables (AIVs) value chain from a gender perspective. AIVs are a woman's crop and as such they have indigenous knowledge which they pass on orally and practically regarding the production, preparation, preservation and uses of AIVs. This knowledge is in danger of being lost if not well preserved and disseminated especially because of increased commercialisation of the AIVs value chain, the loss of the women's share, rural urban migration, and the emphasis on cash crop production.

This paper presents the findings of the HORTINLEA subproject "Gender order: Embedding gender in horticultural value chains to close the productivity gap." The results are based on field research carried out in the rural, peri-urban and urban areas in Kenya. The research employed the use of qualitative methods of data collection such as semi-structured in-depth interviews and focus group discussions with male and female farmers, traders, and respondents from NGOs, research organisations and Government. Qualitative content analysis was carried out using MAXQDA software. The results demonstrated that women have knowledge on AIVs varieties, seed bulking, production processes, medicinal values, ecological sustainability, social networking and methods of AIVs preparation and preservation that contribute to food security and sustainable livelihoods for their households and communities. The paper therefore seeks to discuss methods of oral knowledge preservation and dissemination by universities and policy innovations that can be made by decision makers to make visible the important indigenous knowledge contribution of women to food security.

**Keywords:** African indigenous vegetables (AIVs), gender, indigenous knowledge, policy innovations, sustainable livelihoods, women

## Understanding the Importance of Wage Employment for Rural Development: Evidence from Senegal

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The literature on the rural non-farm economy and non-farm employment often neglects agricultural wage employment. This neglect is rooted in the idea that such employment cannot significantly contribute to household welfare and rural development because it is a low-return and insecure type of employment. In this paper we specifically focus on off-farm wage employment, disentangle different employment sectors, and estimate the impact on household welfare. We use two-round panel data from Senegal, and fixed effects regressions and differencing techniques. We use static as well as intertemporal measures of welfare. We find that entry into wage employment increases per capita income with 140%, smoothens income significantly, reduces the likelihood to be poor with 34% points and the likelihood to become or remain poor with 16%. Despite substantially lower wages for casual and agricultural employment, we find substantial income-enhancing and poverty-reducing effects of such employment. Casual employment is found to at first smooth incomes and to then boost incomes either through upward employment mobility to higher-return jobs or through relaxing investment constraints and increased income from self-employment. We conclude that jobs are important for rural development as they both smooth and boost rural incomes; that the agricultural sector can be an important source of jobs; and that casual jobs can be an important source of upward income mobility. The paper corroborates claims on the importance of the rural non-farm economy but refutes the idea of casual or agricultural employment not contributing to household welfare and rural development. This calls for a reconsideration of the definition of the rural non-farm economy to include agricultural wage employment as a full component.

**Keywords:** Panel data, rural development, Senegal, wage employment

## Why Do Rural Households in Northeast Thailand Invest Less? Consequences for the Development

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In emerging market economies like Thailand, rural development has not received adequate attention in the recent past. The government tends to rely more on specific and often irrelevant agricultural income subsidies (e.g. rice pledging scheme), as well as the rural urban migration, in order to improve the well-being of rural households. However, well-targeted rural development programs are largely missing. As a consequence, the productive investments by rural households have declined. Using a unique panel data set of some 2000 households from over 200 villages in three provinces of Northeast Thailand, this paper analyses the pattern and determinants of investments by rural households. We use two panel waves (2010 and 2013) from the project “Thailand-Vietnam Socioeconomic Panel (TVSEP)”, which included specific investment modules in the survey instrument.

In this paper, we have used a classification approach for different types of investments to identify the investment patterns. To analyse the volume and the determinants of investment, we developed a fixed-effects regression model (FEM). Our results show that the investment pattern has changed profoundly while the overall investments have declined. Rural households invest less in agriculture and more in non-agricultural enterprises, i.e. micro- and small-scale businesses. For investment determinants, we found that education, gender, access to credit, household wealth and the household head's willingness to risk are positively associated with both the propensity to invest and the amount of investment.

The findings of this research provide a scientific basis for designing rural development policies. The basis can effectively foster the improvement of socio-economic conditions in rural villages, in order to reduce the alarmingly high rural urban welfare gap in Thailand.

**Keywords:** Fixed-effect regressions, investments, panel data, rural development, Thailand

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## Exploring the Linkage between Women's Status and Household Food Security in Bhutan

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Despite the wide range of literature supporting the positive linkage between women empowerment and food security, one fails to find its examination in social contexts where females historically enjoyed equality or even favouritism in few cases like maternal inheritance and polyandry. Therefore, this study was conducted in the Kingdom of Bhutan, a landlocked Himalayan country which remained isolated from the world until the 1960s. Literature recognises the prevalence of matrilineal succession and polyandry during the 20<sup>th</sup> century in Bhutan, with its vestiges still remaining in few nomadic ethnic groups.

In this regard, both quantitative and qualitative survey methods were employed with the objectives of (i) investigating women's participation level in crucial domestic decision-making processes of Bhutanese households and (ii) identifying the effect of the level of female involvement in domestic decision-making on households' dietary diversity.

The analyses are based on data collected from 214 randomly selected households living in two central western regions of Bhutan. Employing a recently suggested methodology, women's participation in domestic decision-making is measured and used to estimate its effects on two dietary diversity indicators, i.e. Food Variety Score and Household Dietary Diversity Score.

Descriptive analyses and qualitative interviews reveal that women do not lack any significant participation in domestic decision-making. Besides, the estimations indicate that the relationship between women empowerment and dietary diversity is non-linear. It is estimated that in low levels, increase in female participation in domestic decision-making is associated with positive outcomes. Preliminary analyses indicate that moving towards (perfect) gender equal decision-making regarding household livelihoods positively affects dietary diversity. Thus, this study mainly contributes to filling the gap in gender literature regarding the analyses in social contexts similar to Bhutan where literature supports the presence of polyandry and matrilineal succession. Furthermore, household per capita food expenditure, diversity in agricultural production and the quality of soil are found to be robust determinants of households' dietary diversity.

**Keywords:** Bhutan, dietary diversity, domestic decision-making, gender equality

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## Mothers' Non-Farm Entrepreneurship and Child Secondary Education in Rural Ghana

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While an important share of the rural population in sub-Saharan Africa owns a non-farm enterprise (NFE), it is unclear how these businesses, especially among female owners, contribute to rural development. This study investigates the missing link between rural NFEs and children's education in developing countries. We focus specifically on secondary education, as secondary schooling is lacking behind in enrollment rates compared to primary education. Moreover, while secondary education has received less attention than primary education in the 2000–2015 development agenda, it is high on the international policy agenda for 2015–2030 with a specific target on universal lower secondary education in the Sustainable Development Goals. We empirically analyse the link between NFEs and child education with national representative quantitative data from the sixth round of the Ghana Living Standard Survey (GLSS) and qualitative data from focus group discussions throughout rural Ghana. Using instrumental variable regressions that pass weak and overidentification restrictions, we estimate the impact of mothers' non-farm entrepreneurship on the propensity of child secondary school enrollment. We find a strong significant positive effect of 10.6% points, corresponding to a relative increase of more than 25%. We find a positive effect on Junior High School enrollment but not on Senior High School enrollment, which relates to lower expenses and a better spread in payment for Junior High School education. We test interaction effects between mothers' non-farm entrepreneurship and other important determinants of child schooling. The school-improving effect of mothers' non-farm entrepreneurship is equally strong for boys and girls and for high- and low-educated mothers, and stronger for poorer households. While most of NFEs are small-scale and informal, our results show that even these businesses result in increased investments in child schooling and directly contribute to development. The results imply that NFEs entail the potential to stimulate child schooling among children of low-educated and poor mothers and thereby reduce inequality in rural education.

**Keywords:** Employment, Ghana, non-farm enterprise, rural development, schooling

## **Translation of Gender Awareness into Practice: Experiences from a Nutrition-Sensitive Agriculture Project in Yayu, Southwestern Ethiopia**

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Women in sub-Saharan Africa play a key role for agricultural production and are usually overburdened with work. While issues of gender equality in agriculture have caught increasing attention, the adoption and implementation of gender policies and project agendas at local level remain a key challenge. This research aims to investigate gendered workload and labour division in Ethiopia and to identify possible pathways to improve the status quo. In addition to gender-disaggregated household survey data (n=334), this research uses a qualitative approach, including 30 role-playing-games, 45 semi-structured interviews and four focus group discussions with farmers and officials in four villages in southwestern Ethiopia.

Research results indicate that gender awareness, gained through trainings and media, is not yet translated into daily practices. Despite a high awareness of women's workload among both, men and women, the division of labour tasks is highly gendered and remains unfair. Women work up to five hours per day more than their husbands. While female participation in male-dominated tasks are the norm, male participation in reproductive labour is a cultural taboo. Although all women expressed the desire to be more supported by men, they hardly had any own vision of what could alleviate their workload. However, both male and female participants identified increased male participation in vegetable production as a possible pathway to achieve a fairer distribution of labour. While Ethiopian policies and project interventions address gender inequality at household level, severe problems with the implementation process were identified. Apart from a general lack of staff, the gender knowledge and sensitivity of extension staff is low. While officials indicated that more gender trainings are needed, female farmers perceived trainings as additional workload while not bringing any benefits to them. More research is needed on how gender policies can be translated more effectively at local level in order to induce lasting change of habits.

**Keywords:** Ethiopia, female workload, gender, policy implementation, social change

## Gender Relations in Banana Seed Systems in Banana Bunchy Top Disease Affected Communities in Cameroon

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The study aims to investigate how gender roles shape varietal preferences and decisions-making rights of men and women farmers in banana seed systems value chain in Cameroon. Mixed methods were used to assess access to productive resources, banana productivity, cropping and varietal preferences and decision-making rights between men and women within households in three communities in Ambam District. Sex disaggregated data were collected using quantitative intra-household survey (n=122) and qualitative tools used included 6 sex-segregated key informant interviews and Focus Group discussions (n=68) and observation. Results showed that household banana production is the main activity of men and women farmers for income and food security. It's is largely collaborative, often on separate fields for men and women. Access to the most fertile land favoured households with indigenous male heads. Site selection for banana production was identified as men's activity supported by women's knowledge. Seed selection was mostly done by women, yet men had better access to seed compared to women farmers. Varietal preferences for both men and women was market-driven and thus, there were no differences in preferred choices between both. In all communities, men had greater ownership and control over production resources. Banana production activity is complimentary for men and women farmers which might form platforms for negotiation, compensation and perhaps non-monetary reward system within households. Shock from Banana bunchy top disease (BBTD) on banana production system is therefore likely to demand the contribution of women's roles in seed selection and crop maintenance, thus, providing an opportunity to access to and benefit-sharing in the banana seed value chain.

**Keywords:** Banana bunchy top disease, banana seed systems, Cameroon, gender roles

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## How Does the Commercialisation of Nature Influence Relational Values and Food Security in North-Eastern Namibia?

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In Africa, the relationship and connection of rural people to nature is undergoing changes related to the increased selling of natural products. In rural north-eastern Namibia, the selling of forest timber and non-timber products, as well as river products like fish and reeds, has intensified, risking degradation of ecosystems functions and services upon which the local residents depend for food and income. This study explores how relational values are changing due to the increased selling of natural products in Nambi and Marema villages. The study focuses on relational values as these reveal villagers' shared meanings and moral responsibilities towards the management of natural resources. This study shows how intensive commercialisation of nature is creating conflicts among resource users as their economic and socio-cultural interests and values come to differ. The study also reveals how the emerging conflicts are affecting food security at the village level. Photovoice method was used to collect qualitative data from 20 villagers, to articulate relational values and meanings attached. Villagers' perceptions of the impact of commercialisation of nature on relational values were obtained through 157 structured interviews. Data were analysed with thematic analysis as well as factor analysis. The maintenance of cultural heritage, identity and enhancing social interactions and relations were amongst the most important relational values expressed by villagers. These values are attributed to ecosystems such as the river and not only to single natural feature, such as reeds. Elderly people and individuals who interact with nature beyond interests to gain money (e.g. traditional healers) expressed the most relational values and fear that intensive selling of natural products will cause loss of socio-cultural knowledge and shared values. Further, the culturally important natural features like trees are threatened by the processes of commercialisation, through the institutional settings which are put in place to manage the new markets, for instance, community forests. These are perceived by most villagers to attract outsiders in their own resource system and to generate social conflicts within the village. Research findings indicate that institutional settings such as community forests affect local people's relational values, ecosystem services health and local's accessibility to food.

**Keywords:** Commercialisation of nature, community forests, ecosystem services, Namibia, relational values, rural communities

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## Park-People Relationships and the Importance of Forest Products in the Livelihood Strategies in Rural Thailand

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The creation of protected areas inside forests might promote the goal of conservation but may neglect the livelihoods of rural households if their needs are not considered in the design and implementation of these policies. Forest products are an important source of income, both for subsistence and cash, for many rural households in the Global South.

The research study was conducted in northeastern Thailand in Nakhon Ratchasima Province with the aim to identify the use, role and potential of the forest in the livelihood strategies of the people living in the village Wang Nam Khiao. First, we investigated what characterised the access to forest products, and how the access was mediated. Second, we investigated what income sources were important for the villagers, here including the role of forest products. In addition, we examined the villagers' dependency on forest products and their rationales behind their collection. Finally, we investigated how ecotourism could be an alternative livelihood strategy in the future.

The data was obtained by applying both quantitative and qualitative methods and analysed through several analytical frameworks. It was found that the access to Thap Lan National Park (TLNP) and Sakaerat Biosphere Reserve (SBR) differed greatly through formal and informal arrangements. In TLNP the laws were not strictly enforced and the relationship between the villagers and the TLNP law enforcers seemed well functioning. In contrast, a conflict over access to forest products was exemplified in SBR. Collection of forest products was usually not the main source of income for most households surveyed, but was still important to a certain extent, especially for landless and unemployed households. The forest had different functions such as gap filling, safety net or poverty prevention. It was found that the villagers had many rationales for collecting forest products, both economic and cultural. In a perspective of future sustainable livelihoods around the forest, opportunities such as forest conservation through better harvesting management and ecotourism were explored, and further research would be needed to fully measure the impacts on the villagers' livelihoods of such alternatives.

**Keywords:** Access, dependency, ecotourism, forest products, livelihoods, NTFP, protected areas, Thailand

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## Protected Area Co-Management Initiatives and Policy Change through Foreign Donor in Bangladesh

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Protected areas are seen as central instruments for the conservation of biological diversity as well as wild resources for local livelihood security. Following the 4th World Congress on National Parks and Protected Areas (CNPPA) announcement, Earth Summit in Rio, and the ratification of the Biodiversity Convention, Bangladesh achieved to transform about 10.72 % of the total country's forest area under protected forest area like other developing countries. In 2004, US Agency for International Development (USAID) introduced forest co-management approach that sustains both local livelihoods and the conservation of natural resources. The analytical framework combines concepts derived from policy change process, global governance theorem of direct access to the domestic policy-making process, and the bureaucratic politics theory to explain the access of non-domestic actors and their influence in policy making process of a particular sector. A qualitative-qualitative case study of USAID induced forest co-management development initiatives including a process tracing method was employed to recognize the influence of a foreign donor for policy changes in a recipient country. USAID as a foreign donor has initiated forest co-management development concepts altering or initiating important policy and institutional settings in Bangladesh. The changes were the result of a combination of development inputs and policy instruments including funding, technical assistance, capacity building, training and advisory programs approached from the donor. The study concludes that simultaneously with their formal interest, foreign donors tend to pursue their informal political interests such as policy changes in a sovereign country.

**Keywords:** Bangladesh, bureaucratic politics, co-management, livelihood, policy change, the protected area

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## ***Acacia* Wood Production and Commercialisation Systems for Smallholder Livelihood Development in Central Vietnam**

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Since the 1990s, the Vietnamese government has adopted the policy of allocating degraded forest land for afforestation and sustainable management to smallholder households. This policy aims to achieve environmental objectives as well as simultaneously improve rural livelihoods and forest-based industries. After the restriction of timber harvests from natural forest in 2014, domestic material sources for forest-based industries mainly come from plantation forests of which more than half is under the management of smallholder households. One of the most important species currently cultivated by smallholder is hybrid *Acacia* (*Acacia auriculiformis* × *Acacia mangium*) due to its suitability for local conditions, early benefits and low upfront investment. The *Acacia* hybrid plantations contribute to smallholders' diversification strategy which enables them to reduce farm-risk, increase income and enhance food security. However, a comprehensive analysis of this sector, so far, is lacking.

This paper elucidates the contribution of *Acacia* hybrid plantations and commercialisation in Thua Thien Hue province, where the species has been cultivated since approximately 20 years. 60 household heads in 3 villages of Nam Dong district were interviewed, following a stratified random sampling approach. 6 in-depth household case studies have been conducted to further complement qualitative insights. The findings were validated in group discussions and expert interviews.

Initial results illustrate that *Acacia* hybrid system accounted for more than 70 % of the total timber quantity provided by the plantation forest in Thua Thien Hue province. The crucial position in rural livelihood of such system was unequivocal and sometime it constituted the only income source for smallholders. However, the commercial potential of these plantations wasn't fully utilised as premature harvesting by growers commonly occurred to fulfill their urgent cash demands. Smallholders were also negatively affected by lack of information, limited capital sources and difficult market access. Recommendations refer to the improvement of the productivity and profitability of *Acacia* hybrid plantations and the role of the government, supporting organisations and industry sectors in achieving these targets are delineated.

**Keywords:** *Acacia* hybrid, livelihood, profitability, smallholder, timber, Vietnam

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## The Contribution of the Underutilised Species in the Walnut-Fruit Forests to the Local Livelihoods in Kyrgyzstan

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The walnut-fruit forests in Kyrgyzstan constitute the world's largest wild stands of walnut (*Juglans regia* L.) and are considered among the global conservation hotspots. Previous studies have investigated two complementary pathways of their sustainable use: conservation of the forest resources and at the same time securing the well-being of the local populations who depend on these forests. Walnuts offer the major income source for local peasants, whereas other less utilised forest species in this area still has a significant potential for human nutrition and local livelihoods, the generation of local incomes, and sustainable commercialisation. However, very few studies to date investigated how such resources are currently used and how their benefits are allocated to the forest users.

This study aims to identify which factors influence the collection, utilising and processing of these underutilised forest products; which species particularly contribute to local livelihoods; how the benefits of utilising these species are distributed among the local population; and which pathways might ensure better and more equitable access to and use of these plant resources. A household survey and in-depth interviews were conducted in Kyzyl-Unkur village in the walnut forests (n= 102). Statistical inference methods were applied to delineate the different social strata and track down interrelations among the observed variables. Financial and economic valuation tools were used to establish profitability indicators.

The results show that walnut and wild apple collection is highly commercialised and practiced by the 86 % of the respondents. And a small share of the interviewed households (14 %) collected other types of non-timber forest products (such as wild berries, mushrooms, and medical herbs). Linear regression results showed that the farmers who are part of the cooperatives tend to collect higher amounts of such underutilised products. Although the livestock products are the main alternative income source in the years with low walnut/apple yields, the collection of other species like wild berries, mushrooms, and medical herbs also have a high potential as an alternative income source. To realise this potential better marketing approaches and further improvements of the existing value chains are required (e.g. reduction of middlemen who lower the prices). The advantage of cooperatives (e.g. better access to technology, knowledge, and skills) is another important factor which is needed to be further developed.

**Keywords:** Bioeconomy, Central Asia, food security, forest-based rural development, Kyrgyzstan, underutilised species

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## The Role of Yak for the Livelihood of the People of Gilgit-Baltistan, Pakistan

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The yak (*Bos grunniens* L.) is a long-haired multipurpose bovid animal that can survive in the harsh high mountain areas of Pakistan, where this species is traditionally reared by subsistence-level agricultural households. To study the role of yaks for people's livelihood, a detailed survey was conducted in the Gilgit-Baltistan region of Pakistan, from September 2016 to November 2017. Using a semi-structured pre-tested questionnaire in face to face interviews, information from 200 yak farmers in eight valleys (25 farmers per valley) was collected. Of the interviewed yak farmers, 189 (94.5 %) were males with an average farming experience of  $20 \pm 13.1$  years. They kept an average of  $9.7 \pm 10.01$  yaks, thereof 3.6 adult females. Mostly, yaks were kept for generating offspring (68 % of households), for live animal sale (55 %), and for manure supply (50 %); furthermore, yaks also served to fulfil regular meat requirements (37 %) and those of particular events and festivals (40.5 %). Only 17.5 % of the households milked their female yaks, with an average daily yield of 1.36 liter cow and a significant difference between the 8 valleys ( $p < 0.001$ ). Only 12.5 % of the households sold milk products, for a total annual revenue of 57 € per household. Selling yaks mainly served cash purposes (95.2 % of all cases), and buyers were mostly other farmers (62.7 %), especially from the own municipality (63.9 %). Trading, that is purchasing and reselling of yaks, provided an average gain of 140 € per household and year, with significant differences between valleys ( $p < 0.01$ ), while direct selling of own yak provided an average annual revenue of 577 € per household. Compared to the average annual household revenue from surplus crop sales of 70 Euro, selling of yak, yak products and yak trading proved to be much more relevant income sources. But since the overall productivity of the yak husbandry systems in Gilgit-Baltistan is low, options to improve yak breeding and feeding as well as rangeland management are currently investigated.

**Keywords:** Gilgit-Baltistan, income, livelihood, productivity, sale, yak

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## Shifting from Crops to Livestock: Smallholders' Livelihood Adaptation Dynamics in Nueva Ecija, Philippines

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Sustaining agricultural livelihoods is increasingly challenging for millions of smallholder farmers across developing nations. In the Philippines, farmers are caught between pressures of changes in both social and climate systems. Despite many livelihood development programs, income and food insecurities are prevailing mostly in rural households. Recurring crop failures has hampered the cash crop-oriented smallholders' farming economy. Shifting to livestock-based livelihoods emerged as a buffer activity to recover from production and income shocks due to more frequent typhoons, flooding, and drought. Understanding how farmers take livestock, as transformative opportunity to respond to these changes is important to determine its potential for more adaptive and sustainable smallholder livelihoods. This study explored livelihood trajectories in the context of smallholder households in Nueva Ecija province, publicly known as the rice granary and the national impact zone for water buffalo development programme in the country. The analyses were based on mixed methods i) 30 key informant interviews, ii) 310 farming household survey, and iii) direct observations. Data collection was undertaken from January to October 2016. Findings revealed that farmers' livelihood patterns evolved from the interplay of inter-related causal drivers. Land fragmentation, rapid urbanisation, and extreme climatic events reinforced the decline in farmers' livelihood resources pool. Whereas, the dynamics of change and response depended on the relationships between farm resources, knowledge, and social networks. Recurrent crop failures seriously caused income and market shocks, making local farmers highly risk averse. As a result, shift from rice cultivation to water buffalo dairying was increasingly adopted, that from year 2010, milk became the major contributor to total household income. Coupled with the governmental-led water buffalo development program, such transformative response has balanced farmers dwindling resources, mostly in the form of stable cash incomes, more efficient family labour utilisation, and improved overall household welfare. Therefore, water buffalo dairying can be a viable adaptation option and potential lever to achieve sustainable smallholders' livelihood. Finally, the study proposed a set of key issues for policy and programme consideration.

**Keywords:** Climate change, livelihood transition, mixed crop-livestock, smallholder households, sustainable livelihoods, water buffalo

## Co-Design of Future Farming Systems in Guadeloupe: Techno-Economic Referencing of Agroecological Practices in Crop-Livestock Systems

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This poster presents ongoing research towards the agroecological transition in Guadeloupe, island of the French Antilles, and is part of the AgroEcoDiv project involving INRA, CIRAD and the University of the Antilles. The current agriculture, heavily export-focused, producing sugar cane and banana often in monoculture, is facing increasing problems and instability due to phytosanitary problems, input dependence and instable market conditions. Sustainable solutions are sought to improve especially the situation of smallholders and improve food security. A possible solution are agroecological practices like improved crop-livestock integration, vermi-compost, pasturing on crop residues, and biological pest control. Agroecology suffers however from a negative reputation of uncertainty, impreciseness and being practice of the elder and it thus lies in the responsibility of universities and research institutions to improve this perception. Within the AgroEcoDiv project, a participative approach with a farmer nucleus of 5 community leaders was applied for the innovative co-conception of the ideal future farming system, starting-off on the current one. During this co-design process, a farming system oriented towards high self-sufficiency, performance, efficiency and resilience achieving improved results thanks to the stepwise introduction of agroecological practices was commonly developed. Within this study, the goal is to establish reference values on self-sufficiency, performance, efficiency and resilience of the current and future system to provide a discussion base, which will be crucial for the communication between researchers and farmers during the further co-design and dissemination process. The research shows in how far the new system unites low dependence on external inputs, agrobiodiversity, soil improvement, plant protection and acceptable workload while assuring a monthly income of 2220€., thus proves the agroecological transition for Guadeloupean farmers realistic and gives researchers a useful tool for the dissemination of the step-wise transition amongst small mixed crop-livestock farms in Guadeloupe.

**Keywords:** Agroecology, Carribean, mixed crop-livestock system, participatory, system co-design

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## Adaptation to Flash Floods and Landslides of Rural Households in the Northern Vietnam: An Insight into the Key Drivers

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Flash floods and landslides are recurring disasters adversely affecting to rural households whose livelihood subordinate largely on agricultural production. The study, thus, explores farmer's responses to flash floods and landslides in Yen Bai province, one of the poor provinces in the Northern Mountainous Regions of Vietnam. The determinants of households' choices and the barriers to adaptation, moreover, will also be identified. Household-level data was collected from 405 households in three communes namely: An Binh, An Thinh and Dai Son in 2016, from February to April. The analysis reveals that 97 % of the inhabitants practice at least one adaptation strategy in the context of flash floods and landslides. Adjustment in sowing/planting time, change in cropping pattern and varieties, farm diversification, land use change, selling of home and farm assets, assistance received from friends/relatives/government, borrowing money, applying more pesticides, fertilisers and plant protection products were the main adaptation techniques followed by the farmers. Out of these adaptation strategies, change in cropping pattern and variety, crop diversification, soil management and plant protection are the most adapted methods applied by farmers. Accordingly, to identify the key drivers of household adaptation responses, we used the Multivariate Probit Regression (MNP) model. The results from the MNP model highlighted that age of household head, education level, ethnic group, household status, land ownership, farm size, irrigation, contact with extension service, distance to market, farm income and climate information were the main factors influencing in farmer's adaptation decisions. In addition, money scarcity, lack of machinery and technical equipments, lack of knowledge about flash floods and landslides and insufficient supports from local government were identified as the barriers to adaptation.

**Keywords:** Adaptation, flash floods and landslides, livelihood strategy, multivariate probit model, Vietnam, Yen Bai province

## Beyond the Green Revolution: Thailand's Attempt to Guide Path Dependent Farmers Towards more Sustainable Practices

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In the wake of the Green Revolution, technology deployment and land intensification were introduced in the agricultural sector to trigger the development of Thailand's economy. However, the excessive use of agrochemicals led the Royal Thai Government to implement capacity-building programs for farmers to minimise chemical input. The objective of this study is to understand the rationale behind farming practices in the village of Ban Ba Yai, where farmers remain applying agrochemicals on their fields despite such government programs. To approach this objective, we draw on our interdisciplinary pool of knowledge and triangulate primary data gathered during a field trip in March 2018. We combined both natural and social science methods such as soil and water sampling, questionnaire collection, GPS mapping, semi-structured interviews and participatory rural appraisal (PRA) tools. We organised our findings around rational household decision-making level, drawing on ideas of institutional theories and the agricultural treadmill. Our results suggest that poor soil conditions and lacking market structures create a path dependency impeding an effective shift towards sustainable farming practices. The introduction of new technologies and consequently low commodity prices created a treadmill that challenges farmers to change practices. Moreover, we identified different agencies among villagers that have access to better networks, knowledge or financial means. For the average farmer, it seems difficult to detach input decisions from the market requirements. Adding to this, we identified that farmers' perceptions on sustainable agriculture practices conflict with the government programs as they do not fit with their reality. Overall, our study shows a gap between authorities and local farmers which results in government programs having little effect in creating change. Furthermore, it suggests that a shift towards sustainable farming practices can only be achieved through connecting the capacity building approach with financial incentives. Farmers seem to consider alternative practices only, if they gain an economic benefit from it. Our evidence based results may contribute to future policy design and enable more effective government programs. However, further research on laws and regulatory landscapes in Thailand to facilitate programs adoption is recommended.

**Keywords:** Agricultural intensification, agrochemicals, government programs, Thailand, path dependency, rural livelihoods, sustainable agriculture practices

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## Agricultural Intensification and Land Use Change: Testing the Induced Intensification, Land Sparing and Rebound-Effect Hypotheses with Cointegration

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The growing societal demands for land-based products and services, linked to increasing population, can be satisfied through either clearing new land for agriculture or intensifying production on existing land. Agricultural intensification is promoted as a central strategy to fulfil these demands while reducing the pressure on land. We used cross-country panel data on cropland area and productivity to test three hypotheses on the relationships between agricultural intensification, land use expansion and contraction. The induced intensification hypothesis postulates that restrictions on cropland expansion and increased demand per unit area can induce intensification. The land sparing hypothesis postulates that intensification allows reducing cropland expansion, while the competing rebound-effect hypothesis asserts that intensification, by making agriculture more profitable, can trigger further land use expansion. We used cointegration to disentangle the long-run and short-run causal relationships between the variables. For all crops together, in the short run, we found support for the induced intensification hypothesis for high-income countries, and rebound effect for middle- and low-income countries (due to increases in yield or total factor productivity (TFP) that lead to cropland expansion). In the long-run, the land sparing hypothesis holds for low- and middle-income countries (due to increases in yield negatively affecting cropland area). TFP has a positive effect on yields for low- and middle-income countries. We then test the same hypotheses for specific crops in different contexts, such as soybean in South American countries and staple crops in sub-Saharan Africa. These results show how different conditions in terms of the elasticity of the demand to price changes, potential for land use expansion and trade orientation affect the relations between changes in cropland area and productivity.

**Keywords:** Agricultural contraction, cross-country, agricultural expansion, panel

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## Land Use Change and Agricultural Growth in Rural Vietnam

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In spite of success in poverty reduction on a national level, poverty in some rural areas in Vietnam remains high. Especially in remote and mountainous areas agricultural productivity growth has been low due to poor physical and social infrastructure including limited access to credit and extension advice. In addition land market restrictions have constrained the expansion of land rental markets. However change in agricultural land use is pivotal for agricultural productivity growth and rural poverty reduction. In this study investigate land use change among rural households in three provinces in Central Vietnam. We have organised our study around three questions: (i) what was the extend of agricultural land use change during the past decade; (ii) how much did productivity of land increase during the same period; and (iii) what is the impact of land use change on household income and poverty. Our analysis is facilitated by long-term panel data set established by the Thailand-Vietnam Socioeconomic Panel (TVSEP) which has collected comprehensive household data from about 2000 households in 220 villages in the provinces of Ha Tinh, Thua Thien Hue and Dak Lak over the period of 2007 to 2016. We estimate land productivity at the corresponding changes in agricultural land use patterns and measure vulnerability to expected poverty based on land patterns and productivity changes and controlling for other household covariates.

Our initial results show that agricultural land has declined shifting land to other uses including residential use. We also find that households, with less land tend to invest in perennial crops albeit with limited success based on productivity and income growth. We suggest that our final results have important implications in improving our understanding of the interlinkages between land use, productivity and poverty, especially given the recent trend of declining agricultural land in rural areas in Vietnam.

**Keywords:** Agricultural land, poverty, productivity, Vietnam

## Investments in Agriculture but Trapped in Poverty: Evidence Based on Panel Data Analysis from Vietnam

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Poverty remains a substantial problem in Vietnam. In rural areas, the headcount ratio was still well over 20 % in 2012, with some areas – like in the Northern and Central Highland provinces – reported even higher poverty rates. Most of the poor households rely on agriculture as their main source of income. Increasing agricultural productivity through the adoption of new technologies and investments in agriculture is therefore a major policy concern.

In this paper, we empirically analyse investments of rural households, using a longitudinal data set from the Thailand Vietnam Socio Economic Panel (TVSEP). The analysis is based on data of about 1,800 identical households from three provinces of Central Vietnam, collected in the survey waves of 2010 and 2013. Using a matched difference-in-difference model, we evaluate the impact of investments in agriculture on changes in the poverty status of the panel households over time. We measure consumption poverty by applying the Foster-Greer-Thorbecke (FGT) poverty indices, based on the national basic needs poverty line for rural areas in Vietnam.

Results show that only 16 % of households living below the poverty line undertook investments in agriculture in 2010. By comparing with similar poor households that did not invest, we find evidence that the investments in agriculture reduce the poverty headcount ratio. On the other hand, agricultural investments do not have any significant effect on diminishing the severity of poverty. Our findings suggest the existence of a poverty trap, where extreme poverty decreases the ability to invest in promising income-generating assets and consequently increases the likelihood of remaining poor. Based on our results, we conclude that unless measures are undertaken that enable poor households to invest (e.g. access to credit), the gap in welfare within rural areas is likely to widen.

**Keywords:** Agricultural investments, matched difference-in-difference analysis, poverty, rural development, Vietnam

## Who Should Diversify? Income Portfolios and Household Welfare in Rural Uganda

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Rural households are increasingly diversifying their income portfolios away from agriculture, raising an intensive debate on whether income diversification can foster pro-poor growth and contribute to rural development in sub-Saharan Africa. While the impact of income diversification on household welfare has been extensively studied in the literature, insights on possible heterogeneous effects are scarce. The question of who should diversify has hardly been addressed. In this paper, we provide empirical evidence on the heterogeneous welfare effects of income diversification from the Mount Elgon region in rural Uganda. We use household survey data from two panel rounds in 2014 and 2016, to compare income, poverty and vulnerability dynamics for slightly diversified, moderately diversified and highly diversified households. We apply fixed and random effects regressions to estimate the average welfare effects of income diversification. We estimate heterogeneous effects using panel quantile regressions to address heterogeneity related to the outcome indicators, and use a large set of interaction terms to address heterogeneity related to the explanatory variables. In addition, we attempt to identify causality between income levels and income diversification by exploiting the panel nature of the data. In general we find that income diversification is related with higher per capita incomes, a lower propensity to be poor and reduced vulnerability. Causality is found to run in both directions but with the positive effect of diversification on income being much stronger than the effect of income on income diversification. In particular, we find that with an increase of 10 points in the Simpson index of diversification, per capita income increases with 20.8 % for households in the lowest income quantiles and 9.6 % for households in the highest income quantiles; and the likelihood of being vulnerable reduces with 6.9 % for the lowest vulnerability quantile and with 5.1 % for the highest vulnerability quantile. In addition, we find that the welfare increasing effect of income diversification is larger for larger and younger households with smaller landholdings. Our findings imply that diversified income portfolios can significantly improve household welfare and reduce household vulnerability to income poverty.

**Keywords:** Income diversification, panel quantile regressions, poverty, Uganda, vulnerability

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## Does International Migration and Remittance Lead Agricultural Household to Non-Agricultural Investment? Evidence from a Household Study in Nigeria

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The new economic labour migration state that international migration and remittance can reduce credit constraint and increase household investment. Hypothetically, when extra income from remittance is to be invested, the agricultural household is expected to decide in favour of agricultural investment with higher utility; and as such cross-financing one agricultural activity with another. Nevertheless, researchers have wondered if this is true, or perhaps if migration and remittance may eventually lead migrants' household away from agriculture investment. Although few studies have investigated this issue, no evidence has been provided from Nigeria, the highest migrant-sending and remittance-receiving country in sub-Saharan Africa (SSA).

Using the general household survey data from Nigeria (Living Standard Measurement Study of 2010, 2013, and 2016), we investigated if migration shifts household investment towards non-farm enterprises. Furthermore, we examined the impact of this transition on the household welfare; household consumption expenditure, and food security. For instance, does it increase the likelihood of spending more on food away from home or does it lead to a shortage of household food stock? Furthermore, we studied the impact of this transition on the community food supply. Finally, we show how the livelihood and welfare of households that transit to non-agricultural activities differs from those that remained in agriculture.

Our study is significant as it improves the understanding of how international migration and remittance may or may not be harming agriculture production in SSA. It also shows the implication of this transition on the general welfare of migrant-sending communities. We concluded our study by making policy suggestions on the role of government and institutions (including universities) in improving the investment decision of migrant households.

**Keywords:** Agriculture, food security, international migration, nonfarm enterprises

## Linking Rural Households to Wood Product Value Chains – A Viable Forest Policy for Rural Development in Bhutan?

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Forests provide additional income sources to rural households in many agrarian economies, particularly in periods of seasonal underemployment. This potential seems to be underdeveloped in Bhutan. The country is endowed with significant forest resources, but its forest policies constrain rural households from timber extraction for commercial purposes. The country's persistent environmental conservation policies and constitutional mandate to maintain 60 % of forest cover at all times have resulted in an increase in forest cover over the last decade. Today, more than 70 % of Bhutan's land area is under forest cover and the forest area that could be utilised under sustainable management practices could be more than double as high. However, policies governing the rural population's access to forest were primarily designed to accommodate their subsistence need. Since Bhutan is on track to electrify all households by 2020, the traditional importance of wood biomass as a source of household energy is becoming obsolete. This study uses an economy-wide approach to investigate the potential of forest policies that incentivize rural households to sell fuelwood under different quota regimes to the national wood product value chain including the domestic production of charcoal. Several policy scenarios are simulated, including a variant which would keep timber extraction at today's levels, but would incentivize households to substitute domestic use of wood energy with electricity. We generally find positive welfare effects for rural households, which are predominantly driven by additional employment opportunities in the winter months. Depending on the quota design, electrified households reduce their subsistence use of firewood when facing the trade-off to sell it. The estimated benefits for rural households are likely to be at the lower bound, as we do not account for potential health co-benefits through reduced indoor air pollution. Our study further highlights necessary safeguards for sustainable forest management that ensure compliance with the implemented quota regimes.

**Keywords:** Bhutan, economy wide analysis, forest policy, resource use, rural development, seasonality of labour, wood energy

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## **Livelihood Strategies of Smallholder Rubber Farmers in Southwest China**

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Driven by the rising rubber prices since 2000s, Xishuangbanna Dai Autonomous Prefecture (XSBN), Southwest China, experienced dramatic expansion of smallholder rubber plantation. Rubber has taken over the rural economy and contributed to the reduction of poverty. On the other hand rubber monoculture has increased income uncertainty and has made to become dependent on rubber farming. When rubber prices declined after 2012, smallholder farmers were challenged to mitigate income loss and to develop better livelihood strategies. Evidences from many studies in developing countries have shown that diversifying the sources of livelihood can reduce uncertainty of agriculture. However most of these studies followed a static approach using cross section data. This study is using panel data collected from some 600 small holder rubber farmers in Xishuangbanna collected in 2013 and 2015.

As methodologies we carry out cluster analysis identify typical livelihood strategies based on land and labour as major household resources. To identify the determinants of smallholders' livelihood choices we develop two models: (a) a multinomial logit model and an (b) an ordered logit model to identify the determinants associated with farmers' livelihood practices as well as the factors that cause a shift in livelihood strategies

Initial results show that four groups of livelihood strategies can be differentiated: (i) rubber- dominated, (ii) rubber cum other cash crops, (iii) rubber cum traditional crops, and (iv) highly diversified system. As the major factors that determine livelihood choices of farmers and their changes we identify education of household head and the altitude of household. Even though Xishuangbanna is characterised by diverse ethnic groups, ethnicity is not obvious in influencing household rubber farmers' livelihood strategies options. Our findings offer a good basis for developing local food security policies.

**Keywords:** Livelihood strategies, rubber, smallholder, Southwest China

## Expanding Chinese Farms: A Spatial Panel Data Analysis to Explore the Large-Scale Production Units

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As a result of industrialisation and urbanisation, large numbers of rural workers in China shifted to non-agricultural industries seeking to increase household income, leading to a weak agriculture run by part-time workers. In response, the government has launched a series of policies to encourage farmland transfer from smallholders to various types of large-scale production units. The Chinese agricultural sector therefore gradually evolved from single entities of small-scale farms to the coexistence of small-scale farms and various types of large-scale production units. Yet, it seems that the emergence and expansion rate of large-scale farm operation vary widely across regions. There are also signs of spatial agglomeration effects driven by local socio-economic factors and policies.

To date, very few studies have quantified the drivers of expansion of the large-scale farm sector in China; there is only scarce evidence referring to potential spatial correlations across regions. This paper contributes to the literature by applying spatial panel data models to explain the changes in the share of land cultivated under large-scale farm operation. The model is developed at county-level for the Jiangsu Province in China. The model is calibrated by using county-level statistical data from 2002 to 2015 across 44 counties of the Jiangsu Province. Several preliminary and robustness checks were done. The Moran's I test is first estimated to back the choice of considering spatial interactive relationships; and the results of the spatial panel data models are compared with those of non-spatial panel models. Moreover, both direct and indirect effects are estimated.

Three results stand out: (1) the spatial model is appropriate: the Moran's I values are positive and significant from 2002 to 2015, confirming the rationality of considering spatial interactive relationships; tests to non-spatial panel models further indicate the presence of spatial dependence and the Spatial Durbin Model is proven to be the most appropriate model specification; (2) estimation results suggest that the development level of large-scale farm operation is positively associated with agricultural mechanisation levels and has a U-shaped relationship with cultivated land area per household; (3) estimates of direct and indirect effects show that the economic development level and non-farm employment situation in the county has positive spatial spillover effects on the development of large-scale farm operation while institutional factors like registration of land certificates show negative spatial spillover effects.

**Keywords:** Large-scale production units, spatial autocorrelation, spatial panel data model, spillover effects

## **Towards a Sustainable Sugarcane Industry in India; Improving Water Use, Crop Production and Profits for Indian Sugarcane**

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The sugarcane industry is India's second largest agro-based industry and about 6 million farmers and a large number of agricultural labourers are involved in its cultivation. Sugarcane is a major consumer of water and the decreasing level of the natural groundwater resource threatens food security, economic growth and livelihoods. Decreasing levels of groundwater have in particular influence on production of vegetables and rice which are water intensive crops and crops important for food and nutrition security.

Solidaridad Network Asia with partners have initiated the programme 'Increasing water use efficiency in sugarcane growing in India' in 2016. With support from the Sustainable water Fund, the project intends to enhance both sustainability of sugarcane growing and to raise smallholder incomes. Wageningen Economic Research (WEcR) conducted a baseline study in 2016 for this programme to enable the subsequent evaluation of the socio-economic impact on sugarcane farmers. A pipeline approach was used which clusters the farmers in cohorts based on the year they receive initial support and training (e.g. starting in 2016, 2017 or 2108). The baseline survey was conducted on 1008 farmers.

Baseline results show that good agricultural practices are lacking across all mills and the uptake of drip irrigation is limited, as is knowledge on maintenance. Farmers face financial barriers in the uptake of good agricultural practices and irrigation systems and government subsidies function as financial enablers. The reputation of the mills from the perspective of the farmers influences potential uptake of good practices. Adoption of drip irrigation is not related to higher productivity or gross margins and this requires more attention as it is one of the key elements of the projects' intervention logic.

The mid-term and end-term surveys will be conducted in 2018 and 2020. This will enable to draw robust conclusions regarding the welfare impact and the resource use implications of the project. The underlying theory of change states that mass adoption of water efficient farming methods and techniques will improve water use efficiency in sugarcane farming to the point that water extraction is reduced below the natural replenishment rate and thus contributes to improved food security and livelihoods.

**Keywords:** Evaluation, India, livelihoods, sugar, water scarcity

# Institutions for Irrigation Water Management, Irrigation Technologies And their Impact on Irrigation Performance in Ethiopia

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The Ethiopian Government has considered irrigation agriculture as a primary engine of economic growth in general and to the rural economy in particular. The government plans to increase the current level of irrigation infrastructure three-fold by the end of 2020. However, there has been a concern regarding the performance of existing irrigation systems. Thus, the current study has two interlinked objectives the first is to understand the nature and diversity of irrigation technologies and water management systems at different levels and identify the existing gaps in the sector. Second, it investigates the determinants of irrigation performance and farmers' satisfaction in using and managing irrigation water. Our analysis utilises a comprehensive and unique household and plot-level survey conducted recently in ten districts of the country. In addition, focus group discussion and key informant interview was conducted to gather qualitative data. Nested approach was employed as an analytical framework to examine the existing institutional arrangements related to irrigation water development and management. Our findings show that even if the policies, strategies and the legal instruments are very well specified, and the relevant institutions and organisations have been established, there has been weak enforcement capacity among executed organisations at each level. Moreover, horizontal and vertical communications between ministries and bureaus belonging to different sectors is very weak. Thus, organisations of ministries, bureaus and departments attempt to fulfil their responsibilities without an interdisciplinary and integrated approach which is fundamental in the field of water resource management at each level. At plot level, using ordinal logit model, we analysed factors which affect irrigation performance, using farmers' satisfaction level in using and managing irrigation water as an indicator. In addition to household, plot and village characteristics, water management systems and irrigation technologies significantly affect the performance of irrigation. The results suggest that plots in farmers' and private management systems, that river water is their source of irrigation, apply manual and diesel pump to withdraw water from a source and use drip and furrow irrigation type on their field are found more likely to be in a higher satisfaction category.

**Keywords:** Institution, irrigation, technology, water management system

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## Compromises, Risks and Obligations: Perception of Agrochemicals, Ideology and Health in Huai Phrom, Thailand

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Along with the Green Revolution in the 1960's, technological development and agrochemicals became key elements in the agricultural sector of Thailand. In the light of the Asian financial crisis in 1997, promotion of agrochemicals was replaced with the late King Bhumibol Adulyadej's ideas of Sufficiency Economy and New Theory Farming. Often described as ideological approaches to agriculture, these ideas built upon Buddhist principles such as self-restraint and balanced consumption, aiming at making Thailand's farmers self-sufficient and resilient towards market fluctuations and potential crises.

The aim of this research is to assess the underlying rationales of the agricultural practices in Huai Phrom, a small village located in the northeastern region of Thailand. Promoted as the subdistrict's frontrunner village for practicing sufficiency economy, the dominant agricultural practice in Huai Phrom is characterised by home gardens used for subsistence agriculture, and fields used for cultivating cash crops. The use of agrochemicals constitutes the cardinal distinction between home garden and field, as villagers refrain from using them for their home gardens, while relying on them for the cultivation of fields. This dichotomous agricultural practice was found to derive from a coexisting dependency and dissociation from agrochemicals: Dependency on generating an income, and dissociation deriving from embedded narratives on their negative effects on soil and health. Consequently, circles of debt and economic realities are found to be the underlying rationale behind the willingness to risk health over income.

The research further finds that the monks and officials that are affiliated with Huai Phrom view the small-scale farmers as being morally obligated to contribute to the national economy and society, thus elevating their agricultural practice to having a higher purpose. Hence, the dichotomous agricultural practice is surrounded by an intricate web of contradictory ideas, narratives and discourses, which ultimately urges the villagers to orient their agricultural practice towards concern of society and individual livelihoods simultaneously. The villagers' concern of health, agrochemicals and notions on food safety is ultimately found to be a product of historical shifts in national policy-making, deriving from increasing international pressure to regard food security as a regional and global issue.

**Keywords:** Agrochemicals, cash crops, food safety, health, home garden, livelihoods, new theory farming, self-sufficiency, subsistence agriculture, sufficiency economy, Thailand

## Characterizing the Diversity of Smallholder Farmers for Informed Agricultural Interventions: An Application of Multivariate Analyses in Kapchorwa District, Uganda

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Typologies have been used as tools for dealing with farming system heterogeneity. This is achieved by classifying farms into groups that have common characteristics, that is to say farm types which can support the implementation of a more tailored approach to agricultural development. This study explored patterns of farmer diversity through the classification of 446 smallholder farm households in four sub-counties of Kapchorwa District, Eastern Uganda. Based on the data collected in 2016, the typology was constructed using the multivariate statistical techniques of principal component analysis and cluster analysis. Furthermore, the study constructed an agricultural diversity index to classify farm households by their level of diversity. The index utilised variables including number of crops grown by the household, livestock owned/reared (measured in tropical livestock units), number of fruit trees owned, level of intensification and level of pest management. The Cobb-Douglas production function was used to determine the weights of the different variables used to construct the index. Results indicate that the agricultural diversity index ranged between 0 and 1. Farmers in the lower altitude belt had lower levels of agricultural diversity compared to their counterparts in the mid and upper altitude belts. Overall, the majority of the farmers had medium levels of agricultural diversity between 0.4 to 0.7 as indicated by the diversity index. The study concludes that there is need for a differentiated farm planning and extension intervention than generalising planning across the entire district and the extension system must precisely target agricultural inputs, different cropping practices, market development and market information for identified farm types.

**Keywords:** Agricultural diversity, agricultural diversity index, cluster analysis, Cobb-Douglas production function, farm heterogeneity, farm typology, principal component analysis

## Participatory Needs and Opportunities Assessment as Springboard for Integrated Research and Extension Interventions

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The Participatory Needs and Opportunities Assessment (PNOA) is based on the recognition that the involvement of target beneficiaries as project partners even in the planning stage is a key factor in coming up with relevant interventions. As part of the strategies of the Heirloom Rice Project, the Department of Agriculture commissioned four State Colleges and Universities (SCU's) to lead the PNOA in four targeted provinces. The SCU's were assisted by multi-disciplinary researchers and extension experts from the International Rice Research Institute, PhilRice, Department of Agriculture and Local Government Units. The project sites were indigenous communities that organically produce heirloom rice in terraced paddies. The PNOA was implemented through focus group discussions in 12 selected villages using the transect map, seasonal calendar, hopes and fears and venn diagram as data gathering tools. Outputs were presented in a plenary session for collective validation.

In each village site, results of the PNOA include information on the communities' natural resources and land use, commodities grown, existing infrastructure, health facilities, educational facilities, and service institutions. Another output is a listing of agricultural activities aligned along monthly climatic conditions and occurrences of pests and diseases plotted vis-a-vis the agricultural cycle. Common rice pests identified in all village sites were golden apple snail, rats, stem borer and rice birds. Ninety two percent declared earthworms as pest because they burrow on terrace walls causing water seepage. Major problems include soil erosion causing abandonment of some rice fields, inadequate irrigation during summer, expensive labour, low yields, production pests, lack of customized farm equipment appropriate for rice terraces and scarce post-harvest amenities. Low product price was encountered by farmers who sell part of their produce. Respondents also disclosed farming practices and decided collectively on perceived needs and opportunities.

Based on the PNOA results, the project team updated their integrated research and extension initiatives and provided production, postharvest, capability building and market-related support to the project sites from 2015–2017. From this experience, PNOA is recommended as basis in coming up with holistic research, extension and other essential interventions.

**Keywords:** Participatory assessment, rice pests identification

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# GIZ session

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## **Leveraging Agriculture for Nutrition Outcomes — How Research Can Better Support Development Actions**

JOHN McDERMOTT

*International Food Policy Research Institute (IFPRI), Research Program on Agriculture for Nutrition and Health (A4NH), United States of America*

Reducing stunting and other nutrition impacts are high-level development goals. To improve nutrition, interventions from multiple development sectors, including agriculture are necessary. How can research support nutrition-sensitive agricultural actions? An initial contribution was to systematically generate high-quality evidence of what agricultural interventions improve nutrition and which ones do not. From this portfolio of what to do, examples are provided of how to support programme implementers to improve their performance and how to provide policy makers with information relevant for their enabling role in different development contexts.

**Keywords:** Development actions, nutrition

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## Measuring Women's Empowerment in Nutrition-Sensitive Agricultural Development Projects

ELENA MARTINEZ

*International Food Policy Research Institute (IFPRI), Agri. for Nutrition and Health (A4NH), United States of America*

Many agricultural development projects aim to empower women to improve nutrition, income, or other outcomes. But how do we know which interventions are most effective? The project-level Women's Empowerment in Agriculture Index (pro-WEAI) is a new survey-based index for measuring women's empowerment, agency, and inclusion of women in the agriculture sector. Pro-WEAI is a set of quantitative and qualitative tools that help agricultural development projects assess women's empowerment in a project setting, diagnose areas of women's disempowerment, design strategies to address deficiencies, and monitor project outcomes. Pro-WEAI is being piloted in 13 agricultural development projects in eight countries in Africa and South Asia, including six projects that have piloted pro-WEAI's nutrition- and health-focused add-on modules. This presentation will introduce pro-WEAI and highlight two nutrition-focused projects in Bangladesh and Burkina Faso that are piloting the tool.

**Keywords:** Nutrition focused projects, women empowerment

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## Context-Adapted Dietary Assessment and Nutrition Education Tools for Turkana County, Kenya

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<sup>4</sup>*Bioversity International, Italy*

Turkana County has the highest levels of wasting among children (23 %) in Kenya; 34 % of children are underweight and 24 % are stunted. A critical determinant of malnutrition in developing countries is diet. Yet countries such as Kenya do not have a regular dietary assessment system nor contextually adapted nutrition education tools to raise awareness on healthy diets. From 2016 to 2018, Bioversity International and its partners (NGOs, Ministries, extension workers and universities) collaborated in a BMZ/A4NH-funded project to develop and test context-adapted novel and existing tools for dietary assessment and nutrition education purposes aiming to improve dietary quality for women of reproductive age and small children aged 6 to 23 months in Turkana County. The tools were co-developed and adopted by local stakeholders, and introduced to several other organisations at national level.

The project documented a rich diversity of edible plant and animal species with different functional classifications (95 different food plants of which 66 were wild). Despite this apparent diversity, diets are limited in diversity (only 20 % of women and 28 % of small children achieved the minimum recommended dietary diversity) with very low consumption of fruits and vegetables. Wild plant foods provide a huge potential of reducing diet cost, as well as fulfilling nutrient requirements, but their potential must be assessed on individual and location-specific basis. Indigenous knowledge systems, due to their high acceptance in local communities, offer new potential for nutrition communication and promotion of local agrobiodiversity use.

Our next step consists of introducing the integrated community-based approach for farm, market and diet diversity. The successful approach, developed in Vihiga County, western Kenya, involves communities, guided by extension workers, NGOs, policy makers and researchers, to design, implement and evaluate their own agriculture for nutrition interventions to improve use and benefits of seasonally available biodiverse nutritious foods.

**Keywords:** Nutrition focused projects

## Nutrition Sensitive Agriculture: Experiences out of Ethiopia

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In Ethiopia, about 38 % of children under five years of age are chronically malnourished and 57 % are anemic. The soil's nutrient status affects human nutrition through the quantity and the quality of food produced in subsistence agriculture. National-level soil sampling has shown that Ethiopia's agricultural land is deficient in a number of macro- and micro-nutrients such as zinc and iron. It is therefore not surprising that around 38 % of children under five years are chronically malnourished and 57 % are anemic.

Agronomic biofortification aims to increase the content of selected micronutrients, including zinc, iodine, iron and others in staple food crops. In the Ethiopian highlands, two GIZ implemented projects viz the Nutrition Sensitive Agriculture Project (NSAP) and the Integrated Soil Fertility Management Project (ISFM+) collaborate with CIMMYT to test the potential of agronomic biofortification to improve crop yields and grain micronutrient content on farmers' fields through the application of micronutrients (zinc, iron, iodine) on cereal crops. The objective being to improve crop production, quality and ultimately human nutrition.

Results from exploratory on-farm trials conducted in 2015 and 2016 indicated that the type of micronutrients and fertiliser application methods had an impact on crop yields and grain micronutrient content. Foliar zinc application was found to be effective in improving grain zinc content in wheat and teff (an annual grass native to Ethiopia and Eritrea) whereas the combination of soil plus foliar application worked better for barley. Foliar iron application resulted in significantly higher grain iron content in barley (38.1 %) and wheat (26.4 %) than their corresponding controls; however, no difference was observed in teff. Regarding foliar iodine fertiliser application, teff and barley showed significant increases in grain iodine content due to the treatment. In conclusion, the findings suggest that:

- Responses consistently showed increases in grain micronutrient content due to treatments;
- Agronomic biofortification through the use of micronutrient containing fertilizers is a viable method for increasing grain micronutrient content, and thus potentially increasing micronutrient consumption by rural households;
- Different crops responded to treatments in different ways, suggesting that one application type may not be ideal across crops.

**Keywords:** Ethiopia, nutrition, micronutrients, soil fertility

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# A4NH - Leveraging agriculture for nutrition and health outcomes

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## **A4NH Session: Leveraging Agriculture for Nutrition and Health Outcomes**

### *Research Program on Agriculture for Nutrition and Health (A4NH)*

The CGIAR Research Program on Agriculture for Nutrition and Health (A4NH) links consumption – of healthy, affordable, and safe foods – with supply, offering an innovative perspective on the relationship between agriculture, nutrition, and health through research that strengthens the knowledge base and new partnerships that lead to real outcomes.

A4NH focuses on addressing challenges related to food system transformation, reducing the occurrence of micronutrient deficiency, the rising burden of foodborne disease, improving the effectiveness of public programs and policies for nutrition and emerging health risks, like antimicrobial resistance. The programme recognises addressing inequality related to gender or other social categories is a development objective in its own right, and an important condition for achieving improved nutrition and health.

As CGIAR's only research programme on nutrition and health, A4NH brings a unique multi-sectoral perspective to the system-level outcome of improving food and nutrition security for health. Recognizing the magnitude of the task, A4NH is led by IFPRI and managed by a group of four other CGIAR centres (Bioversity International, CIAT, ILRI and IITA and two academic institutions (Wageningen University Research and the London School of Hygiene and Tropical Medicine), and brings together the talents and resources of other CGIAR Centers plus a wide range of partners, to carry out research activities through five unique, yet complementary, flagship programs and three cross-cutting units in at least 30 countries.

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## **Improving Nutrition through Agriculture – What Have We Learned and How Can We Support SDG Outcomes**

JOHN MCDERMOTT

*International Food Policy Research Institute (IFPRI), Research Program on Agriculture for Nutrition and Health (A4NH), United States of America*

The CGIAR's Agriculture for Nutrition and Health (A4NH) Programme, begun in 2012, was designed to better leverage agriculture interventions for improved nutrition. Since then, significant progress has been made in understanding the agriculture pathways for improved nutrition and evaluating the contributions of agriculture interventions to nutrition and health impacts. Multiple pathways for improving nutrition rely on women's empowerment. In addition, much has been learned on how to augment agriculture interventions with nutrition education.

For achieving SDG outcomes, country ownership and leadership are critical. Countries are seeking to improve nutrition through multiple sectors, including agriculture and food systems. This requires navigating dietary transitions, strengthening country ownership of programs and investment decisions, convening public with private and civil society partners, and better understanding drivers that shape demand.

Also important in the A4NH approach is assessing different impact pathways and how actors along these pathways contribute to nutrition and health outcomes and impacts. A systematic approach to planning and assessing such theories of change will be described with some examples. This will then be further elaborated in a subsequent panel discussion by A4NH research leaders.

**Keywords:** Agriculture, impacts, nutrition, outcomes, theories-of-change

## **Pathways and Theories of Change for Nutrition and Health Outcomes from Agriculture, Examples Across Food Systems, Biofortification, Food Safety and Integrated Programs and Policies**

NAMUKOLO COVIC<sup>1</sup>, INGE D. BROUWER<sup>2</sup>, JEFF LEROY<sup>3</sup>, ERICK BOY<sup>3</sup>,  
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Each programme area in A4NH considers how its research outputs lead to immediate and intermediate development outcomes and benefits for beneficiaries. Three of the A4NH programme areas work through markets and value chain pathways. For food systems (Inge Brouwer), we take a more systemic view of food actors and how they interact to improve diet quality. For biofortification (Erick Boy), very specific supply chains by crop and country are assessed through detailed assessments of supply chains and how they function. For food safety (Kristina Roesel and Fred Unger), theories of change, rely on understanding risk behaviours and incentives and how they can be influenced. In all these programme areas, the assumptions behind the theories of change are compiled in evidence tables in which we evaluate the strength of evidence for different assumptions on how outcomes and impacts are achieved.

Other A4NH programs, such as integrated nutrition-sensitive agriculture programs (Jef Leroy) work through public, often combinations of health, agriculture and social protection, programme implementers. Research is designed to evaluate and provide evidence with programme implementers on what and how to deliver programs. Across all A4NH programme areas, enabling actions (Erastus Kang'ethe) of government, civil society, private sector and academia and how these come together can be assessed with a mixture of qualitative and quantitative measures.

**Keywords:** Agriculture, health, impact pathways, implementation, nutrition, policy, theories of change

# BMEL session

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## Invited Paper

MATIN QAIM:

**Keynote to the Panel Discussion: Does Diversified Agricultural Production Automatically Lead to Improved Nutrition?** 554

## Panel Discussion

SILVIA DIETZ:

**Panel discussion: Does Diversified Agricultural Production Automatically Lead to Improved Nutrition? Research projects supported by the Federal Ministry of Food and Agriculture, BMEL**

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## **Keynote to the Panel Discussion: Does Diversified Agricultural Production Automatically Lead to Improved Nutrition?**

MATIN QAIM

*University of Goettingen, Dept. of Agricultural Economics and Rural Development,  
Germany*

Undernutrition, low dietary diversity, and micronutrient deficiencies remain big problems in many developing countries. A large proportion of the people affected are smallholder farmers. Against this background, it is often assumed, that further diversifying small-farm production could be a good strategy to improve dietary diversity and nutrition. But is there really such a clear link between production diversity on the farm and dietary diversity in the farm household? In this overview, key factors that can influence this relationship are discussed, including issues of measurement. Empirical evidence from various developing countries is presented. Farm production diversity is positively associated with dietary diversity in some situations, but not in all. Especially when production diversity is already high, the association is not significant, or it can even turn negative when diverse production entails lower cash incomes due to foregone benefits from specialisation. Markets seem to be more important for dietary diversity than subsistence production.

The evidence from selected countries is supplemented with a systematic review and meta-analysis of the available literature. Using transparent selection and inclusion criteria, 45 original studies were identified, reporting results from 26 countries and using various indicators of diets and nutrition. While the majority of these studies highlight positive associations between production diversity and dietary diversity and/or nutrition, in less than 20 % of the studies positive and significant associations were found for all of the relationships analysed. Around 60 % of the studies report positive associations only for certain subsamples or indicators, the rest found no significant associations at all. The mean marginal effect of production diversity on dietary diversity is positive but small. On average, farms would have to produce 16 additional crop or livestock species to increase dietary diversity by one food group. The mean effect is somewhat larger in sub-Saharan Africa than in other regions, but even in Africa farms would have to produce around 9 additional species to increase dietary diversity by one food group. While results may look differently under very specific conditions, there is little evidence to support the assumption that increasing farm production diversity is a highly effective strategy to improve smallholder diets and nutrition in most or all situations.

**Keywords:** Dietary diversity, nutrition, production diversity

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## **Panel discussion: Does Diversified Agricultural Production Automatically Lead to Improved Nutrition? Research projects supported by the Federal Ministry of Food and Agriculture, BMEL**

SILVIA DIETZ

*Federal Ministry of Food and Agriculture (BMEL), Head of Division Research and Innovation, Germany*

The Federal Ministry of Food and Agriculture (BMEL) established the funding instrument 'Research Cooperation for Global Food Security and Nutrition' to strengthen Germany's contribution to agricultural and nutritional research. The funding instrument is applied to develop efficient food systems in partner countries, while building long-term partnerships between agricultural and nutritional research institutions in Germany, Africa and Southeast Asia.

Two calls for proposals have been published in 2013 and 2016. The first call focused on diversified agriculture for improved and nutrition-sensitive diets. A total of eight international research consortia, each with a duration of 3 years, were launched between 2014 and 2016. Subject of the second call was the improved processing of local food to reduce seasonal food insecurity as well as food and nutrient losses. In this context, seven research consortia will be funded by the end of 2018.

Funding agency is the Federal Office for Agriculture and Food (BLE).

The BMEL-Session at the Tropentag 2018 presents a panel discussion on the question: "Does diversified agricultural production automatically lead to improved nutrition?"

The panel consists of members from different project consortia in the nutrition context funded by BMEL:

1. Prof. Dr. Matin Qaim (keynote), Georg-August-University of Göttingen – Project leader: "Agriculture and Dietary Diversity in Africa (ADDA)"
2. Dr. Harry Hoffmann, Leibniz Centre for Agricultural Landscape Research (ZALF) – Project leader: "Scaling-up Nutrition - Application of nutritionally sensitive and diversified agriculture for improved food security (Scale-N)"
3. Dr. Irmgard Jordan, Justus-Liebig-University of Gießen – Project leader: "Crops for Healthy Diets - Linking Agriculture and Nutrition (HealthyLAND)"
4. Dr. Gudrun Keding, Center for Development Research (ZEF), University of Bonn – Senior Scientist: "Diversifying agriculture for balanced nutrition through fruits and vegetables in multi-storey cropping systems (NutriHAF)"

**Keywords:** Diversification, nutrition-sensitive agriculture, research cooperation, sub-Saharan Africa

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# UGent Research in Africa

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## Land Restoration in Tigray (North Ethiopia) – A Result of Science and Policy Interactions

JAN NYSSSEN<sup>1</sup>, MITIKU HAILE<sup>2</sup>

<sup>1</sup>*Ghent University, Dept. of Geography, Belgium*

<sup>2</sup>*Mekelle University, Dept. of Land Res. Manag. and Environ. Protection, Ethiopia*

Since at least three millennia, agriculture is practised in north Ethiopia, and the adaptation of the agronomy to soil and climate variability is nearly optimal. However, land management has for long been hampered by unequal access to land, prevalent stubble grazing and wood harvesting. Concomitant land degradation reached its paroxysm in the 1970s-1980s, with infamous famines. Thereafter, intense land reclamation took place.

Over the last three decades we used an array of geomorphological and environmental research methodologies in the northern Ethiopian highlands (particularly in Tigray) to better understand changes in the landscape, focussing on processes, their rates and spatial variability. Multispectral satellite imagery was also involved, as well as the interpretation of historical aerial and landscape photographs and their recent repeats, what allowed mapping land use and cover since the late 19<sup>th</sup> century and the development of timelines of vegetation cover and soil and water conservation.

In line with our findings on land resilience, and as a flagship for good governance, the Tigray region received the 2017 Future Policy Gold Award from the World Future Council. (<https://www.worldfuturecouncil.org/press-release-fpa-2017/>). In our presentation we address the past and the future of land management in northern Ethiopia. How did the status of soils and forests change over the last century? Which land management strategies can be followed to enhance sustainable output from soil, water and forest resources? What are the backlogs? Ethiopian farmers have proven to be good individual land managers, but can they also be good land use planners? How does all this impact on people's livelihoods?

**Keywords:** Famine, food production, land degradation, land resilience, world future council

## Cooperatives and Food Security: Trade-Offs in Ethiopian Multipurpose Cooperatives

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It is paradoxical that small-scale farmers who provide a majority of the food in the poorest regions of the world, continue to be prone to food insecurity. Although small-scale food production is important for household food security, farmers face many challenges and constraints which impacts their productivity levels. Constraints faced by small-scale farmers relate to lack of access to land and water, poor physical and institutional infrastructure, limited ability of small-scale farmers to transport inputs and produce, and lack of capital assets, information and access to services and financial markets, amongst others. Cooperatives (coops) are acknowledged as important organisations to tackle these constraints while aiming at improving yields and income of member farmers through pooling resources and efforts. Through their collective benefits, they aim to secure ecological, social and economic empowerment. Interventions for both food and cash crops may induce food availability and accessibility and as such, contribute to realising the SDGs No poverty and Zero hunger. Yet, the ultimate impact cooperatives make, will depend on how much their services match the requested support needed to overcome the constraints that famers face. In this paper we consider the multipurpose cooperatives in Ethiopia which are typically set up to provide inputs and market services to farmers. Instead of studying farmer level effects, which are well-described in literature, we focus on cooperative-level decision making. We use data collected from 180 multipurpose cooperatives in the Tigray Region to assess their potential to contribute to food security. By comparing the functioning of these cooperatives and their priority impact activities, we try to assess the inherent trade-off cooperatives make between supporting food and cash crop production. We study how important these cooperatives perceive it to contribute to the different potential pathways of impact (including direct pathways through food production and food diversification, and indirect through employment and improved income), and try to identify key intervention areas.

**Keywords:** Cooperatives development, food security, small-scale farmers

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## Knowing Your Allies: Profiling Urban Dairy Farmers in Ethiopia

ELINE D'HAENE, MARIJKE D'HAESE

*Ghent University, Department of Agricultural Economics, Belgium*

Demand for animal produce is expanding in developing countries because of a growing population, progressive urbanisation and rising per capita income levels. Given the projection that half of the African population will live in cities by 2035, the possible contribution of urban agriculture (UA) cannot be underestimated. Especially not in Eastern Africa which is believed to become the world's most rapidly urbanizing area in the coming decades.

To be able to fulfil future milk demand, the Ethiopian government launched the Livestock Master Plan in August 2015 to promote the take-off of the dairy sector. The ambitious target is set to double domestic cow milk production by 2020. Urban dairy production systems will play a key role in achieving this goal during the first development stages as milk markets are still poorly developed in Ethiopia due to high transaction costs. But (urban) farmers don't look alike, they have different motivations, skills and ambitions, are in different development stages and experience different constraints, resulting in a variety of management profiles of these small 'enterprises' i.e. which inputs/outputs are used/generated, from/to who inputs/outputs are sourced/sold, production scale etc. Therefore it is imperative to gain insight in the profiles of urban dairy farmers before setting out appropriate interventions and policies.

This paper aims to (1) classify urban dairy farmers based upon production performance and coping strategies during the multiple fasting periods of the Ethiopian Orthodox Church which alter the country's national milk demand, (2) to characterise the identified clusters, (3) to identify strengths, weaknesses, opportunities and threats of each cluster and (4) to put forward appropriate interventions tailored to each farmer group to improve urban milk supply.

**Keywords:** Cluster analysis, farm classification, farm efficiency, farm resilience, urban agriculture

## ***Taenia solium*, the Most Important Foodborne Zoonotic Parasite: Is Elimination Possible? An Example from Zambia**

SARAH GABRIËL, TINE DE COSTER FOR THE CYSTISTOP GROUP

*Ghent University, Department of Veterinary Public Health and Food Safety, Belgium*

*Taenia solium*, the number one foodborne parasite (FAO/WHO), has been extensively studied in Zambia in people and pigs, and found to be highly prevalent. Human act as final hosts, with the adult tapeworm lodging in the intestines (taeniosis) and excreting eggs into the environment via the stool. Pigs, the intermediate hosts, obtain the infection via ingestion of infected stool/feed/water contaminated with parasite eggs which develop into cysticerci (porcine cysticercosis), primarily in the muscles. People acquire the tapeworm via consumption of insufficiently cooked infected pork. However, human can also act as accidental intermediate host when ingesting food/water contaminated with eggs, and develop cysticercosis. The cysticerci have a tendency to lodge in the central nervous system and cause neurocysticercosis. With 57 % of people with active epilepsy diagnosed with probable or definitive neurocysticercosis in Zambia, suggesting *T. solium* to be the single most important cause of epilepsy, control is urgently needed. We have assessed the impact of different control interventions on occurrence of *T. solium* in people and pigs in the Zambian setting.

In an ongoing intervention study, the use of human mass drug administration (praziquantel) and health education; combined with pig treatment (oxfendazole) and vaccination (TSOL18 vaccine) in a four-monthly administration system for six iterations has been assessed for its potential to eliminate the parasite's transmission. This study 'elimination' study arm (5 villages and 2 farms, 1,210 people, 520 pigs) is compared with a 'negative control' study arm (7 villages, 1,272 people, 591 pigs). At baseline, 16 % and 27 % of the people tested taeniosis and cysticercosis positive, respectively. Fifty six percent of the pigs were found infected, with no differences between the study areas. After the 6 interventions in the elimination study arm, only 4 % of the tested pigs were found positive versus 50 % of the pigs from the negative control study arm. Further results and challenges encountered will be presented.

**Keywords:** Cysticercosis/taeniosis, elimination, One Health, *Taenia solium*, Zambia

## Rice Sheath Rot Complex in Mali and Nigeria – A Contrasting Tale of two Different Worlds

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During an extensive survey of rice fields across West Africa, sheath rot symptoms were notably observed in Mali and Nigeria. The objectives of this study are (i) to identify the pathogens associated with sheath rot symptoms on rice, and (ii) to ascertain the roles of the different pathogens associated with sheath rot of rice in Africa. In Nigeria, two rice fields were sampled at Chanchaga and Ibadan while a rice field was sampled in the arid Selingue, Mali. Molecular characterisation results revealed that in Nigeria, rice sheath rot associated pathogens were predominantly *Sarocladium oryzae* (65 %), *Fusarium spp.* (20 %) and *Burkholderia gladioli* (2 %). However, in Mali, we found mainly *Fusarium sp.* (50 %) and *S. oryzae* (10 %). *S. oryzae* isolates from both countries clustered in three genetic groups whereas five different *Fusarium* species were found in both countries. Using indigenous rice varieties from Mali and Nigeria, pathogenicity studies with *S. oryzae*, *Fusarium spp.* and *B. gladioli* isolates revealed that *S. oryzae*-Group III isolates were the most pathogenic on both FARO 44 (Nigeria) and ADNY11 (Mali) rice varieties. Furthermore, pathogenicity tests using representative *Fusarium* isolates on both rice varieties showed that *F. andiyazi* from Ibadan-Nigeria was the most pathogenic *Fusarium* species. *B. gladioli* isolates were mildly pathogenic in comparison with the other two pathogens. Also interesting was the observed interaction between *S. oryzae* and *Fusarium* species, which are likely due to the production of secondary metabolites by either or both pathogens. Future work will focus on the Nigeria scenario in order to elucidate the *Sarocladium-Fusarium* interaction and the interplay of both in the incidence of the rice sheath rot complex.

**Keywords:** *Burkholderia gladioli*, *Fusarium spp.*, rice sheath rot complex, *Sarocladium oryzae*

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